RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA

VOLUME XLV

Published by order of the Government of India

28841
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CALCUTTA:
SOLD AT THE OFFICE OF THE GEOLOGICAL SURVEY,
27, CHOWRINGHEE ROAD

LONDON: MESSRS. KEGAN PAUL, TRENCH, TRÜBNER & CO.

1916

28841/36

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RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

Part 1.] 1915. [February.

NEW SIWALIK PRIMATES AND THEIR BEARING ON THE QUESTION OF THE EVOLUTION OF MAN AND THE ANTHROPOIDEA. BY GUY E. PILGRIM, D.SC., F.G.S., *Officiating Superintendent, Geological Survey of India.* (With Plates 1 to 4 and two text figures.)

SOME of the material, now described, was in my hands as long ago as 1910 and formed the basis for the establishment of one new genus, *Sivapithecus*, and two new species, *Dryopithecus punjabicus* and *Semnopithecus asnoti*. Time did not then allow me to do more than publish the briefest notices of these forms[1]. Further material has since been from time to time discovered, which abundantly confirms my first conclusions, and the time seems now to have arrived, when a full and detailed account of the whole should be published. The material now at my disposal obliges me to establish two additional species of *Dryopithecus*, *D. chinjiensis* and *D. giganteus*, and another new genus, *Palæosimia*, with the specific name of *rugosidens*.

When Lydekker investigated the Indian fossil Primates between the years 1879 and 1885, very little was known about the age of the beds which had yielded them, or of their correlation with the mammal horizons of Europe. Fresh facts on this subject have accumulated during the last six years, and the results so far obtained have been summarised by the present writer[2] in a paper published in 1913.

[1] Pilgrim, Notices of new mammalian genera and species from the Tertiaries of India, *Rec. Geol. Surv. India*, XL, p. 63 (1910).

[2] Pilgrim, The correlation of the Siwaliks with mammal horizons of Europe, *Rec. Geol. Surv. India*, XLIII, p. 264 (1913).

Although the exact locality, from which the specimens, belonging to the earlier collections, came, is still doubtful, yet the following is the most probable horizon of the various Indian fossil Primates now known :—

Presbytis (Semnopithecus) entellus (?)	Karnul caves	Pleistocene.
Simia cf. satyrus	Upper Siwalik (upper zones.)	Upper Pliocene.
Papio falconeri Lyd. . . .		
Papio subhimalayanus Meyer .		
Presbytis (Semnopithecus) palæindicus Lyd.		
Macacus (?) sivalensis Lyd. . .	Dhok Pathan zone.	Pontian.
Cercopithecus (?) asnoti Pilg. . .		
Palæopithecus sivalensis Lyd. .		
Dryopithecus giganteus Pilg. .	Nagri zone .	Lower Pontian.
Dryopithecus punjabicus Pilg. .	Nagri and Chinji zones.	Sarmatian.
Sivapithecus indicus Pilg. . .		
Palæosimia rugosidens Pilg. . .	Chinji zone .	Sarmatian.
Dryopithecus chinjiensis Pilg. .		

The most interesting features connected with the recent discoveries are:—

1. The evidence afforded of the widespread distribution of the genus *Dryopithecus*, which supports the theory, already prevalent, as to the close affinity of African and Asiatic anthropoid apes with the genus *Dryopithecus*.
2. The knowledge of the complete upper dentition of *Dryopithecus*, now for the first time discovered, and hitherto known only by isolated molars.
3. The possession by the genus *Sivapithecus* of characters, which more nearly resemble those of Man than is the case in any other genus of anthropoid living or fossil, except perhaps, the Pleistocene *Pithecanthropus* and *Eoanthropus*. The occurrence of such a type as far back as the sarmatian is strong evidence that the line of Man's descent diverged from that of the other anthropoids at a very early date. The co-existence of these essentially human characters with others which are no less certainly primitive, though they have persisted in the apes, and have even been retained in some small degree by early specimens

of mankind, points to some closely allied form to *Sivapathecus indicus* as the direct ancestor of Man.

In that case it would seem that we may quite reasonably anticipate the discovery of true Man, at least in Pliocene strata, since the differences between Palaeolithic Man and his assumed sarmatian predecessor are not so great as to render it unlikely that the interval of time occupied by the pontian stage should be sufficient to obliterate them from a generic point of view.

4. The characters common to the Gibbon and *Sivapithecus* and not shared by the other living apes, point to *Sivapithecus*, and therefore Man, being an early offshoot from the Gibbon line.

The evidence for these conclusions is amplified and discussed at the end of the present paper. We shall be in a better position to estimate its value when the detailed description of the specimens has been given. I shall, therefore, proceed at once to the systematic portion, in which the *Cercopithecidae* will be treated separately to the anthropoid apes.

CERCOPITHECIDAE

CERCOPITHECUS (?) ASNOTI Pilgrim

PLATE I, FIGS. 1—3.

1910. *Semnopithecus asnoti* Pilgrim, Notices of new mammalian genera and species from the Tertiaries of India, *Rec. Geol. Surv. India*, vol. XL, page 64.

The fragment, upon which this species was founded, was very briefly noticed by the writer in 1910 in the paper quoted above. It was there referred, on exceedingly feeble evidence, to the genus *Semnopithecus* (now to be known as *Presbytis* by virtue of the laws of priority of nomenclature), and the specific name of *asnoti* was given to it.

I may preface my remarks by suggesting the extreme probability that the fragment is generically indeterminable. It consists only of a portion of the immature right maxilla of a Cercopithecid monkey (Ind. Mus. D. 120), containing the first molar (unworn), the last milk molar (greatly worn) and the last premolar, which has been developed out of its position *in alveolo*, by cutting away the side of the jaw beneath the last milk molar.

A left maxilla (Ind. Mus. D. 121), containing two unworn molariform teeth, the larger of which is identical in size, shape and structure with the milk molar in the last mentioned specimen, probably belongs to a very immature individual of the same species, the two teeth it contains being then mm^3 and mm^4.

These specimens were collected by Sub-Assistant M. Vinayak Rao from the neighbourhood of the village of Hasnot, in the Salt Range area, and from the nature of the matrix were almost certainly derived from the Dhok Pathan zone of the Middle Siwaliks.

Another tooth (Ind. Mus. D. 182), exactly similar to the first molar in the type maxilla, was collected from a locality which is well known to me, about 1 mile north-east of Domeli railway station on the road to the village of Chakwa. This is situated nearly 20 miles to the north-east of Hasnot and its stratigraphical position is, undoubtedly, in the Dhok Pathan horizon.

The dimensions of these teeth are as follows:—

—		Ind. Mus. D. 120.	Ind. Mus. D. 121.	Ind. Mus. D. 182.
M^1	length	8·2	..	8·5
	breadth	8·0	..	7·4
	height	5·9	..	5·4
Mm^4	length	6·9	6·5	..
	breadth	7·0	6·7	..
	height	..	4·6	..
Pm^4	length	6·8	..	..
	breadth	6·8	..	..
	height	..	..	..
Mm^3	length	..	5·6	..
	breadth	..	5·5	..
	height	..	3·4	..

The four cusps of the molars, connected in pairs by exactly transverse ridges, and the shape of the premolar leave us in no doubt that we have to deal with a member of the Cercopithecidae.

Since, however, the teeth of the different genera belonging to this family are remarkably like one another, differences in the proportion, which the individual teeth bear to one another, form often the only means by which their dentition can be distinguished. In the absence of the two hinder molars we are debarred from such a comparison.

On the assumption that the specimen belonged to *Presbytis* (*Semnopithecus*), then the presence of the broad anterior shelf, projecting slightly on the external wall of m^1 as well as mm^4, afforded a marked difference from the corresponding teeth of any species of *Presbytis* known to me. This was indicated in my preliminary note on the specimen. This shelf is formed by the continuation of ridges which run forward from the two anterior cusps. In the present species the external portion of the shelf is separated from the external cusp by a furrow which runs vertically half way down the external wall of the crown.

I have since discovered that this feature is a constant character of the African genus *Cercopithecus*. It does not seem to be shared by *Macacus*, *Colobus*, *Cercocebus*, *Mesopithecus*, *Libypithecus* or *Dolichopithecus* any more than by *Presbytis*. In *Dolichopithecus*, indeed, such a shelf would appear to be altogether absent, the anterior cusps standing quite near the edge of the tooth[1]. On the other hand in that genus there is a distinct external cingulum, having no connection with the anterior cusps and situated nearer the base of the crown.

An additional point of distinction is afforded by the shape of pm^4, which had not been exposed when I wrote my preliminary note. This tooth in the specimen under consideration is characterized by the long distance from the summit of the transverse crest to the posterior border of the tooth, as compared with that between the summit and the anterior border. In *Macacus* the two distances are the same and the tooth as a whole is rather short. In *Presbytis* the tooth is longer than in *Macacus*, and the posterior is longer in proportion to the anterior part of the tooth, but not so markedly so as in the Hasnot tooth. Neither *Dolichopithecus* nor *Mesopithecus* show this feature. On the contrary something of the same kind is found in *Cercopithecus*.

[1] Depéret, Les animaux pliocènes du Roussillon, *Pal. Mém. Soc. Géol. France*, 3 (1890) p. 11.

In weighing the evidence in favour of assigning the specimen to one genus rather than to another, I consider that we are bound to take account of these two features, trifling though they may seem, which it shares in common with the genus *Cercopithecus*, but, as far as I am aware, with no other. Supposing it were ancestral to the living African monkeys, which are placed in *Cercopithecus*, we should, perhaps, hardly expect it to have the large dimensions which are actually the case. Consequently, it is more probable that it represents a lateral branch from the *Cercopithecus* stock. In calling the specimen *Cercopithecus* (?), I, therefore, only mean to draw attention to what seem to be its most probable affinities, while admitting the likelihood that more complete material would show it to be distinct generically from *Cercopithecus*. The pontian age of the Hasnot specimen would indeed *a priori* incline us to a belief that its genus is not the same as the recent one, but it is necessary to await further material before giving effect to such a belief.

The geological significance of such an affinity with an African type in an Indian pontian species is noteworthy, in so far as it points to a period in the lower Miocene, when free intercommunication existed between the two continents. From a species, which was then common to the two areas, may have sprung on the one hand the modern African *Cercopithecus* and on the other Indian forms, of which this pontian species may be the first representative that has so far come to sight.

The fauna of the lower Miocene beds of the Bugti hills in Baluchistan[1] affords the best proof at present known of the close similarity at that geological period between the mammalian faunæ of India and Africa.

MACACUS (?) cf. SIVALENSIS, Lydekker

PLATE I, FIG. 4.

1878. *Macacus sivalensis* Lydekker, Notices of Siwalik Mammals, *Rec. Geol. Surv. India*, vol. XI, p. 66.

1886. *Macacus sivalensis*, Lydekker, Indian Tertiary and Post Tertiary Vertebrata, *Pal. Indica*, series 10, vol. IV, p. 5.

In 1878 Lydekker described under the name of *Macacus sivalensis* two fragments of maxillæ belonging to a Cercopithecid monkey,

[1] Pilgrim, The Vertebrate fauna of the Gaj series in the Bugti hills and the Punjab, *Pal. Indica*, new series, vol. IV, mem. 2 (1912), pp. 1—83.

which were obtained by Theobald in the neighbourhood of the village of Hasnot in the Salt Range. From the character of the matrix still left on the specimens, there is little doubt that they were derived from the Dhok Pathan horizon of the Middle Siwaliks.

I suppose the author of the species would be the first to admit the possibility that more abundant material would oblige us to separate it generically from the living genus. He, however, has adduced arguments which render it probable that the affinities of these maxillæ lie with *Macacus*, and it is, therefore, obviously unreasonable to refer them to any other genus, though one may be allowed to regard the reference as provisional.

A few years ago Sub-Assistant M. Vinayak Rao obtained from the middle Siwaliks of Hasnot a fragment of the right mandibular ramus of a Cercopithecid monkey (Ind. Mus. D. 181), which is the subject of the present notice. It is figured in Plate 1, fig. 4, and contains two perfect, well worn, molariform teeth, of which the smaller is in a more advanced state of wear than the larger. Behind the latter is the alveolus of another double-rooted tooth, and on the other side of these are the alveoli of two roots pointing to the former existence of at least one tooth, as large or larger than the one behind it, forming a slight curve with the hinder three. Immediately beneath the anterior margin of the smaller of the two perfect teeth, a sharp curve may be noticed in the lower edge of the ramus, which evidently marks the beginning of the symphysis. Behind this point, the side of the ramus drops almost vertically from the base of the tooth crowns to the lower edge of the ramus, without any bulge or ledge such as is often present on the inner side of the mandibles of monkeys. On the outer side, the mental foramen is visible 7·3 mm. from the base of the ramus, beneath the alveolus of the foremost of the four teeth, of which more or less distinct traces are left.

It may be gathered from this description that there can be no doubt that the dentition in this mandible is the permanent one, which is confirmed by the absence of any permanent premolars in the jaw below the two teeth which are preserved. The latter are therefore m_1 and m_2 and the tooth in the front of the jaw is pm_4.

The dimensions in millimetres of the mandible and of the individual teeth are as follows:—

Thickness of ramus beneath m_2		6·8
Depth of mandible below m_1		18·3
M_2	length	6·6
	breadth	5·9
M_1	length	5·8
	breadth	5·2
Approximate length of pm_4		7·2

On comparing this with the maxilla of *Macacus sivalensis*, figured by Lydekker, it is evident that the animal to which it belonged must have been almost of the same size. Further, the proportionate dimensions of the teeth are identical, so far as can be gathered, with those of the corresponding upper teeth of Lydekker's specimen, so that, other things being equal, a provisional reference to the species *Macacus sivalensis* is reasonable, since the specimens came from the same locality and horizon.

The most striking characters of this mandible are its depth and slenderness. These eminently characterize *Macacus* as distinguished from *Presbytis*. I am unable, however, to find that these characters enable us to distinguish it from *Cercopithecus*.

Some significance may be found in the apparent narrowness of the shelf in front of the anterior crest of the molars. This is a character of the genus *Dolichopithecus* as seen in the species *D. ruscinensis* from the Pliocene of Rousillon[1]. It is however much more pronounced in that genus. The advanced state of wear of the molars in the present mandible tends to cause the anterior cusps to run into this shelf and so appear nearer the margin than is really the case. The actual breadth of this shelf is probably almost the same as in the upper molars of the maxilla of *Macacus sivalensis*, in which it is narrower than in many macacques and decidedly more so than in the genus *Cercopithecus*.

A cingulum at the antero-external corner of m_2 and in the middle, externally, between the two crests, is similar to that which is present in *Dolichopithecus*. I have, however, seen a similar cingulum in specimens of *Macacus nemestrinus*.

The long alveolus of pm_4 in the Hasnot mandible points to a tooth which is rather longer than is usually the case in *Macacus*, and is more like pm_4 of *Dolichopithecus*.

[1] Déperet, l. c.

In conclusion, I have very little hesitation in referring this mandible and the maxilla from Hasnot, described by Lydekker, to the same species, and there seems no justification for removing them from the genus in which Lydekker placed the latter. The species may be regarded as showing features which indicate some affinity with the European Pliocene genus, *Dolichopithecus.*

SIMIIDAE

DRYOPITHECUS PUNJABICUS, Pilgrim

PLATE I, FIGS. 5, 6. PLATE II, FIGS. 4, 5. PLATE III.

1910. *Dryopithecus punjabicus*, Pilgrim, Notices of new mammalian genera and species from the Tertiaries of India, *Rec. Geol. Surv. India*, XL, p. 63.

1913. *Dryopithecus indicus* (lapsus calami), Pilgrim, The correlation of the Siwaliks with mammal horizons of Europe, *Rec. Geol. Surv. India*, XLIII, p. 311.

1913. *Palæopithecus* sp. Pilgrim, The correlation of the Siwaliks with mammal horizons of Europe, *Rec. Geol. Surv. India*, XLIII, p. 320.

The types of the present species are portions of the right and left ramus of the same mandible, the former containing m_3 with half the broken crown of m_2 and the latter m_2 with the broken crown of m_3. The specimens were found near the village of Chinji by Sub-Assistant Vinayak Rao, and though their exact locality has not been recorded, there seems very little doubt that they came from the Chinji zone of the Lower Siwaliks. There is some ground for supposing that they occurred at the very summit of that zone, partly because the matrix attached to them consisted of a hard reddish clay, free from concretions and similar to a fossiliferous clay, which is known to occur to the west of Chinji, near the boundary between the Lower and Middle Siwaliks, partly, also, because the maxilla found at Haritalyangar in the Simla Hills, which seems almost certainly to belong to the same species as the mandible, occurs in beds, which are known both by their fauna as well as their stratigraphical position to be newer than the Chinji zone, though they represent a low horizon of the Middle Siwaliks, to which the name of the Nagri zone has been given[1].

The species may therefore be referred in terms of European geological horizons, either to the upper sarmatian or the lowest pontian.

[1] Pilgrim, The correlation of the Siwaliks with mammal horizons of Europe, *Rec. Geol. Surv. India,* XLIII, pp. 270, 319.

Mandible.

The mandible, evidently, did not belong to an old animal, as m_3 is half concealed, in side view, by the ascending ramus, while this tooth is inclined at a slight angle to the one in front of it. The breadth of the ramus at m_3 is considerable —19·8 mm. The depth at m_2 is only 23·4 mm., but might no doubt have increased a little as the animal got older. As the ramus is broken off immediately in front of m_2, it is impossible to perceive if the depth of jaw increased anteriorly as in *Dryopithecus fontani.*

Last lower molar.—The dimensions of this tooth are as follows: length 12·5 mm., breadth 10·4, height 6·7. It is thus longer than broad, its greatest breadth being near the front end, whence the sides of the tooth converge backward to a rather narrow hinder tip, so that the general shape of the tooth might almost be described as sub-triangular, differing in this way from *Dryopithecus rhenanus*, but still more from *D. fontani* and *D. darwini.* The inner side of the crown descends steeply to the base, but the outer side less steeply, still by no means so gradually as in *D. darwini.* From both edges the slope towards the centrum of the tooth is extremely gentle. The five main cusps of the anthropoid lower molar are well marked, though, as in *Dryopithecus* generally, they are not high. The least worn and therefore the highest is the metaconid. The entoconid is smaller and lower than the metaconid. The protoconid and hypoconid are about equal in size and height. The mesoconid is both smaller and lower than either of the other two outer cusps. These three outer cusps are arranged in a curve, the hypoconid being situated more inwardly than the protoconid, and the mesoconid more so than either. The entoconid also lies nearer the centrum than the metaconid, so that the tooth tapers symmetrically.

Besides the main cusps there are two secondary cusps, which may be distinguished from the numerous swellings on the main cusps by the fact that fairly deep furrows running from the edge of the crown to the centrum delimit them from the five main cusps. These occur between the metaconid and the entoconid and between the entoconid and the mesoconid.

The main furrows, which separate the cusps, already mentioned, from one another, are precisely similar to those which Abel[1] has described so fully in the case of *Dryopithecus darwini.* As in the case of

[1] Abel, Zwei neue Menschenaffen aus den Leithakalkbildungen des Wiener Beckens, *Sitz. kais. Akad. Wiss. Wien* CXI, Abt. 1 (1902) p. 1185.

that species, the furrows between the three outer cusps only descend on the external wall of the tooth as far as a cingulum, which unites the cusps in question at rather less than half the distance from the cusp summit to the base of the crown. Here they dichotomize within the cingulum. On the other hand, the furrow between the entoconid and the secondary cusp which intervenes between it and the metaconid, runs right down the wall to the base of the crown. The furrow, however, which separates this secondary cusp from the metaconid is very faintly marked on the internal wall of the tooth. The remaining furrows, which are very numerous, are naturally associated with and equal in number to the various enamel ridges, and their course, where necessary, will be described in connection with the latter.

These enamel folds are much more plainly to be seen on the inner side than on the outer side of the tooth, and are especially well marked on the metaconid. If, however, the outer cusps were less worn, there is no reason to suppose that the folds would be any shallower or less numerous. Both protoconid and metaconid send a strong crest obliquely to the front edge of the tooth, which is raised into a somewhat weaker ridge, behind which is a hollow. Another pair of ridges run from protoconid and metaconid towards one another, curling round into the just mentioned hollow. There are no less than four other folds on the sides of the metaconid. One of these produces a cusp, visible in side view on the inner side of the tooth and separated from the main cusp of the metaconid by a deep furrow, which starting from the edge runs towards the centrum. It soon dichotomizes and its branches run into the furrow, which separates the metaconid from its secondary cusp. The two remaining folds, of the four mentioned above, produce two ridges, which start some way down from the summit of the metaconid and run as far as the centrum. The anterior secondary cusp is also divided by one fairly strong and two weak furrows, running towards the centrum. Similar furrows, but much more feebly marked, are to be seen on the entoconid; traces of these can also be seen as furrows on the external wall of the tooth. Both the hypoconid and the mesoconid are too much worn to show any very distinct trace of folding.

Beyond the folds mentioned and a few others of limited extent, but all of which are visible to the naked eye, there is no trace of the fine rugosity with which the entire surface as well as the sides of the tooth in *Dryopithecus darwini* would appear to be covered.

On the contrary the surface of the tooth, even on the little worn metaconid, is quite smooth and polished between the various furrows.

The cingulum still remains to be mentioned. This exists only in the form of a broad shelf or ridge, which links the bases of the protoconid and hypoconid and to a smaller extent of the hypoconid and mesoconid. It does not extend beyond these limits; there is consequently no trace of the cingulum which in *Dryopithecus darwini* goes right round the antero-external angle of the tooth.

The hinder root of this tooth is strongly produced backward. There is a distinct oval polished face on the front wall of the tooth caused by the contact against it of the tooth in front.

Second lower molar.—This tooth is shorter than m_3, but broader in proportion, its dimensions being, length 11·6 mm., breadth 9·9 mm., height 5·4 mm. It is much more worn than m_3, and therefore the various folds, which are plainly visible in that tooth, are either very indistinctly so or are even entirely effaced in this. It does not possess the tapering shape of m_3, because the hypoconid is not nearer the centrum than the protoconid nor the entoconid than the metaconid. Thus the sides of the tooth are parallel. The mesoconid is, however, strongly displaced inward, so that the hinder end of the tooth is narrower than the rest of it, but lacks the symmetry of m_3. The secondary cusp between the entoconid and the mesoconid is very weak; in consequence, the hollow at the hinder end of the tooth is much more pronounced. The cingulum, linking together the bases of the protoconid and hypoconid and of the hypoconid and mesoconid is quite distinct.

A comparison of these two molars with those assigned to one or other of the three previously known species of *Dryopithecus* leaves no doubt in my mind as to the propriety of referring this mandible to the same genus. From Man, as well as from each of the living genera of anthropoid apes, *Dryopithecus* differs in the greater excess of length of m_3 over m_2. This is shown in the table on page 72.

From Man, the Chimpanzee, Orang, Gorilla and also from the fossil genus *Sivapithecus*, the molars of *Dryopithecus* differ by being less broad in relation to their length. This is rendered clearer by the breadth indices tabulated on page 70.

The hindermost cusp, mesoconid, is more strongly developed in *Dryopithecus* than in Man, the Gibbon, Chimpanzee and Orang. This weakness of the mesoconid is especially noticeable in m_3; in fact in the genera mentioned the mesoconid in m_3 is often altogether wanting.

The folds or wrinkles on the surface of the crowns of the teeth offer a means of distinction, although it seems likely that this is often a character which varies within the same genus according to its stage of development, and may, therefore, only be of specific importance. Thus, although the teeth of Caucasian man are not characterized by more than a few strong wrinkles, those of the fossil man[1] of Krapina and some of the lower races have the surfaces of the molars rather richly covered by them. Moreover, the wear of individual fossil specimens may easily deceive one as to the strength of the feature in question. Nevertheless, their strong development in the Orang distinguishes that genus not only from *Dryopithecus* but also from every other so far described. Equally the absence of wrinkles distinguishes the Gibbon as well as *Pliopithecus*. The folding of the enamel in *Dryopithecus* is very much less in intensity and frequency than in the Orang. The wrinkles in the Chimpanzee are often numerous but are very much finer than those of *Dryopithecus*. The Gorilla has sometimes very numerous and very strong folds on the molar surfaces. In Man, as observed before, the wrinkling appears to be variable, but the folds, though occasionally as strong or even stronger than in *Dryopithecus*, are not so numerous. In *Sivapithecus* the folding of the enamel is, like Man, coarser, but less frequent than in *Dryopithecus*. *Neopithecus brancoi* has much feebler wrinkles. Moreover it is distinguished from *Dryopithecus* by the much greater length of m_3.

Each one of the distinctions enumerated above is as applicable to the teeth under consideration as it is to *Dryopithecus*. They agree in every detail relating to the arrangement of the cusps and the folding of the enamel, with the lower molars of *Dryopithecus rhenanus*, as described and figured by Schlosser[2] and to a smaller extent with *Dryopithecus darwini* as described and figured by Abel[3]. I am quite unable, therefore, to refer the Punjab mandible to any other genus. I may, however, point out some additional features, in which my specimen may be distinguished from certain genera which approach it somewhat nearly in regard to the characters already detailed. Thus,

[1] Gorjanovic-Kramberger, Der diluviale Mensch von Krapina, *Mitt. d. Anthrop. Gesells. Wien.*, XXXI, (1901), p. 190, pl. 2, 3.

[2] Schlosser, Beitrage zur Kenntniss der Saugethierreste aus den sud deutschen Bohnerzen, *Geol. u. Pal. Abhandl.* IX, (1902), pt. 2, p. 124.

[3] Abel, l. c., p. 1185.

the breadth index of the Gorilla sometimes does not exceed that of these teeth by much, while the folding is sometimes equally intense. The Gorilla is, however, easily distinguished by the exceedingly deep furrows which separate the main cusps, apart from the inferior length of m_3 in relation to m_2. Besides the points already mentioned, *Sivapithecus* differs by the higher cusps, the complete absence of a cingulum and the absence of secondary cusps.

A comparison with *Palæopithecus* is much more difficult, both because that genus is known only by the upper dentition, and also because the upper teeth are in such an advanced stage of wear that one cannot be certain either of the height of the cusps or of the nature of the enamel folding. The enamel is, however, very much thicker than in the mandible now before us, and it seems almost certain that the cusps in the unworn tooth of *Palæopithecus* were higher and more massive, while the wrinkling of the surface must have been of an altogether coarser type. It may, perhaps, be permissible to be influenced by the fact that the maxilla from Haritalyangar, to be described later, shows much clearer evidence of belonging to a different genus from *Palæopithecus*. On the other hand this maxilla exhibits a structure and details of sculpture so analogous to those of the lower molars from Chinji as to oblige me to assign them to the same species.

It remains now to see how this mandible differs from those which have hitherto been assigned to the genus *Dryopithecus*[2].

These may be said to be four in number, since, as Abel has emphasized, there are two distinct types of tooth referred to *D. fontani*, which in my opinion cannot be regarded as belonging to the same species, if even the same genus. These four species may be given as follows. *Droypithecus fontani*, type 1, Lartet. *D. fontani* type 2, Harlé[1], *D. rhenanus*, Pohlig, *D. darwini*, Abel. Of these *D. fontani*, type 2 has the greatest breadth index; next to this comes *D. darwini*, the breadth in the case of this species being due to the strong cingulum; *D. fontani* type 1 is the next highest, if Harlé's measurements

[1] Harlé, Nouvelles pièces de Dryopithèque de Saint-Gaudens, *Bull. Soc., Géol., France*, (3) vol. XXVI, (1899) p. 304, pl. 4.

[2] I regret that Dr. A. Smith Woodward's paper on a lower jaw of *Dryopithecus fontani* from the upper Miocene of Lérida (Spain), published in the *Quart. Jour. Geol. Soc. Lond.*, vol. 70, p. 316, Dec. 1914, did not reach me in time to enable me to insert in the text any reference to this specimen or to Dr. Woodward's interesting remarks on the symphysis of *Dryopithecus*. These do not, however, appear to be inconsistent with the views on anthropoid evolution expressed by me in the latter portion of the present paper. The approximate dimensions of the molars in the Lérida specimen are included in the table on page 70.

were intended to be quite accurate; *D. punjabicus* comes next, while *D. rhenanus* is the lowest of all. These, however, form such a gradual series that no serious specific distinction can be based on this character, though it is interesting to observe that the order is in agreement with the supposed geological age of the different species.

It seems more important to observe that the length of m_3 as compared with m_2 is much greater in *D. punjabicus* than it is in *D. fontani*. This may be correlated with the taper shape of m_3 in *D. punjabicus*, due to the displacement towards the centrum both of the mesoconid as well as of the entoconid. M_3 of *D. fontani* is distinguished by being but little narrower in its posterior than in its anterior part, the three outer cusps forming a straight line. The displacement of the mesoconid towards the centrum is greatest in the species *D. rhenanus*; *D. darwini* and *D. punjabicus* are, perhaps, equal in this respect. On the other hand, m_3 in *D. rhenanus* does not taper in the symmetrical fashion so characteristic of *D. punjabicus*, because the entoconid in the former species is not displaced and is larger than in the latter. M_3 of *D. darwini* would, really, be far more like the Punjab species in this, were it not for its very broad and pronounced cingulum. This cingulum is present, but less strong in *D. fontani*, but is generally absent in *D. rhenanus*, though Schlosser[1] mentions a molar which shows what appears to be a connecting shelf between the protoconid and hypoconid similar to what occurs in *D. punjabicus*. It is perhaps permissible to emphasize the greater distinctness of this external cingular shelf between each of the two pairs of outer cusps in the Punjab species than in *D. rhenanus*. It would seem that *D. darwini* has fewer main foldings on its molar surface than *D. rhenanus*, but that it is characterized by the presence of a fine series of wrinkles indiscriminately over the surface of the tooth as well as on the sides. This type of wrinkling is absent from *D. punjabicus*, as it is from *D. rhenanus*. The Punjab species, however, seems to possess an equally strong and numerous series of large scale foldings, although differences in the stage of wear make it difficult to estimate the real strength of the foldings, especially when the actual specimens are not at hand for comparison. In *D. punjabicus* a series of rather deep furrows on the internal side of the tooth, which extend a short way down the wall of the tooth and in side view produce a dis-

[1] *Schlosser*, l. c. p. 126.

tinct serrated margin on both the metaconid as well as the entoconid, appears to be especially characteristic of this species.

The height of the molars is greater in *D. punjabicus* than in the other species. On the other hand, the individual cusps appear to be slightly lower than in *D. rhenanus*, although a comparison with a cast of m_3 of *Dryopithecus darwini*, which Professor Abel has been kind enough to send me, shows no difference between my species and Professor Abel's.

In conclusion, although this mandible is near enough to each of these other species of *Dryopithecus* to leave no doubt as to its generic position, there are such differences as to render it impossible to place it in any one of them rather than another, and justification seems to be afforded for specific distinction.

Maxilla.

Some years later than the discovery of the mandible just described, Sub-Assistant Vinayak Rao found at Haritalyangar, in Belaspur, one of the Simla Hill States, a beautifully preserved right maxilla (Ind. Mus. D. 185), containing the two premolars and the front two molars; this specimen is figured in Plate III. I at first referred it to the genus *Palæopithecus*, as a species more primitive than the species *P. sivalensis*. This, however, was before I had been struck by the remarkable analogy in structure and ornamentation between these molars and those of the Chinji mandible. In addition to the four teeth mentioned, the fragment shows the adjoining portions of the alveoli of the canine and of m^3 as well as the base of the jugal process. The edge of the maxilla above the canine is intact. The following are the dimensions in millimetres of the four teeth :—

—	M^2.	M^1.	Pm^4	Pm^3.
Length	10·6	10·4	6·6	7·0
Breadth	11·4	11·3	9·7	9·5
Height	5·6	5·3	5·5	6·2
Breadth Index	107·5	108·6	146·9	135·7

Penultimate upper molar.—This tooth is constructed on the usual plan of anthropoid upper molars and consists of four main cusps. Of these, the paracone is slightly stronger than the metacone and *the protocone considerably stronger than the hypocone. All the cusps fall very gently towards the centrum and steeply away from it, the outer walls of the tooth being distinctly steeper than the inner walls. The protocone and the metacone are connected by a strong ridge, running obliquely across the tooth, and the protocone* and hypocone by an equally strong one, which forms the inner edge of the tooth. The protocone and paracone are also connected by a continuous ridge, parallel to and not far from the front edge of the tooth. Besides this, an oblique crest runs from the outer corner of the paracone towards the front edge, where it meets another similar but slightly weaker one proceeding from the protocone. Between this and the last mentioned ridge is a deep furrow, which is continued, though weakened, over the paracone and a small way down the external wall of the tooth. Six smaller folds run down from near the summit of the paracone towards the main valleys which separate that cusp from the protocone and metacone. The corresponding furrows run a short way down the outer wall of the tooth and produce in side view a serrated edge, which reminds one of the similar appearance on the internal edge of the lower molars. Three corresponding ridges, but less distinct owing to the greater wear on that side, run from the protocone towards the centrum, anterior to the connecting crest between the protocone and metacone. The metacone has three folds which produce crenations on the outer edge. The folds on either side of the crest uniting the protocone and metacone are almost entirely obscured by wear. A strong ridge runs backwards from the metacone to the hinder edge of the tooth and meets a corresponding and equally strong one from the hypocone. One or two obscure folds descend on the front side of the latter ridge into an exceedingly deep cavity, from which a deep furrow proceeds between the hypocone and the connecting crest between metacone and protocone. On its way towards the inner edge of the tooth this furrow dichotomizes. The front branch runs up towards the protocone and does not reach the edge, but the hinder branch runs down to the base of the crown. The main furrow between the paracone and the metacone also runs down the external wall to the base of the crown. Between these various folds the enamel surface is absolutely smooth and polished.

A faint trace of a cingular connection between the protocone and hypocone can just be made out.

This tooth has three roots.

First upper molar.—This tooth wants the postero-external corner of the metacone. It is slightly inferior in length and breadth to m^2, but is broader in proportion to its length. Almost exactly the same sculpture can be distinguished on the surface of this tooth as on the last, only it is not always so plain on account of its more advanced wear. The only important differences are the somewhat stronger hypocone and the presence of a very strong ridge, in addition to those mentioned for m^2, which connects the hypocone with the metacone, running right across the hinder cavity of the tooth. A faint trace of a cingular connection between the paracone and the metacone can also be just made out. M^1 is three-rooted.

Hinder upper premolar.—This tooth is much broader than long, and consists of an inner and an outer cusp, both of which fall equally steeply towards the sides and the middle of the tooth. The outer cusp is higher than the inner one. Both have strong ridges, running forward and backward from the summit, though they are stronger in the case of the outer than of the inner cusp. Two strong ridges run from each, parallel to the hinder wall of the tooth, to meet in the mid line. The foremost of these two ridges is continuous right across the middle of the tooth, but the hinder one is cleft by a median furrow. Two additional transverse ridges run from the ends of the anteroposterior ridges mentioned above and form the front and back edges of the tooth respectively. Three deep cavities, one median and the others anterior and posterior are formed between these ridges. These two latter stand at a lower level, that is nearer the base, than the median cavity. The posterior one of these is continued by a furrow, which passes over the outer edge of the tooth and can be seen on the external wall. An additional short fold runs down from the summit of the outer cusp into the hinder cavity. This tooth is three-rooted, the roots being divergent.

Front upper premolar.—The front wall of this tooth is not parallel to the hinder wall, owing to the forward prolongation of the antero-external angle, which makes the external side of the tooth longer than the internal side. The internal side is actually shorter than the corresponding side in pm^4, while the external side is longer than in pm^4. In other respects, the structure of the two premolars is very similar. There are the same four cross ridges, of which the hinder of the two central ones is cleft by a median furrow. The foremost cavity sinks, however, to a lower level than in pm^4, while the foremost of the ridges is continued as a strong crest on the external wall of the tooth, with a corresponding furrow in connection, which runs down to the base of the crown. Additional short ridges run from the summits of both cusps into the central cavity. This tooth has also three divergent roots.

The dimensions of these teeth, the moderately low cusps, the complexity of the folding of the enamel, and, above all, the peculiar serrated outer edge of the molars incline one so strongly to the opinion that we have before us a maxilla and mandible which belong to the same species, that, unless fairly conclusive evidence were forthcoming of a close affinity to another genus, or of the existence of features in the maxilla, which told against an affinity with *Dryopithecus*, I should feel fairly certain that the similarity mentioned between the mandible and the maxilla indicated specific identity.

The only upper teeth of *Dryopithecus* known are the two molars from the Suabian Bohnerz of Melchingen, figured both by Branco [1] and Schlosser[2] and described in detail by the latter. One of these is almost unworn and shows the foldings perfectly; the other is badly worn. Certain details of the enamel sculpture are not as plainly shown on the Haritalyangar specimen as on the Bohnerz tooth, owing to the more advanced wear of the former, but, apart from minute differences, the two agree so closely as to make it fairly certain that they belong to the same genus.

I know of no other upper molars, which approach these at all nearly in structure. Those of Man and the Chimpanzee are distinguished by their much less complicated system of folds, especially in the hinder part of the tooth. Man and the Orang have distinctly broader molars, the excess of breadth over length being particularly marked in m^2. The upper, like the lower molars of the Orang, are clearly distinguished from these by the profuseness of the wrinkles, with which the whole surface of the crown is covered. Gorilla approaches these teeth somewhat in the complication of the folds, but can easily be distinguished by the elevated cusps and the deep furrows which separate them from one another. The molars of the Gibbon exhibit not only the same

[1] Branco, Die menschenahnlichen Zahne aus dem Bohnerz der schwabischen Alb. *Jahresheft. d. Vereins f. vater. Natur. Wurttemburg*, LIV (1898), pp. 1-144.
[2] Schlosser, l. c., p. 125.

deficiency of the main folds, which has been noticed in the case of Man and the Chimpanzee, but the secondary folding is almost entirely absent. The latter character prohibits any near affinity with *Pliopithecus*. *Neopithecus*[1] is known only by the last lower molar, but the smaller breadth index of this is indicative of narrower upper molars than is the case in *Dryopithecus*. Its folds are also feebler. *Griphopithecus*[2] is clearly distinguished from the present specimen and from the upper molars of *Dryopithecus rhenanus*, by its exceedingly large breadth index, by its very much simpler structure and by the absence of the finer system of folding. *Pithecanthropus* has molars at least as broad as *Griphopithecus*. *Palæopithecus* has a very massive hypocone, which, however, is so closely approximated to the protocone and to the ridge connecting the protocone with the metacone, as to leave no room for the complicated system of ridges and folds which *Dryopithecus* shows in this position. In consequence of this, also, the breadth index of the *Palæopithecus* molar is considerably in excess of what it is in *Dryopithecus*. The badly worn condition of the maxilla of *Palæopithecus* occasions a doubt as to the details and intensity of the sculpture, but it is likely that in the unworn tooth the cusps were higher, the folding less, but coarser, and the enamel thicker than in the Haritalyangar species. The differences in the premolars of *Palæopithecus* will be commented upon later. *Sivapithecus* alone remains; this is known only by lower teeth, which are also little worn. Judging, however, by the massiveness of the cusps, the greater coarseness of the folds, the high breadth index and other mandibular features, which indicate a nearer affinity to Man than other apes exhibit, it is unlikely that the Haritalyangar maxilla belongs to the same genus as the *Sivapithecus* mandible.

Having reached the conclusion that this maxilla belongs to the genus *Dryopithecus*, the differences from *Dryopithecus rhenanus*, the only species of *Dryopithecus*, in which the upper molars are known, may be summed up as follows. The breadth index of the molars is greater. The cusps are probably lower. The outer cingulum is less clear. In the Haritalyangar maxilla the furrows on the outer cusps cross the edge of the tooth, and so produce in side view a serrated appearance, which appears to be absent from *Dryopithecus rhenanus*.

[1] *Neopithecus-Anthropodus brancoi*, Schlosser, l. c., p. 119. Abel, l. c., p. 1173.
[2] Abel, l. c., p. 1177.

We may now proceed to discuss the affinities of the premolars—the first upper premolars of the genus *Dryopithecus*, which have so far come to light. The most characteristic feature of these teeth is the existence of the two well marked central ridges which connect the inner and outer cusps. This character is quite in accord with the intensity and number of the folds which the molars of *Dryopithecus* exhibit. In Man and the Gibbon, there is no trace of them, the single central cavity being bounded solely by the anterior and posterior ridges, which form the front and back edges of the tooth. *Palæopithecus* seems to show a trace of the same structure, so far as it is possible to make out the details on a crown that is nearly worn down. In *Palæopithecus*, the anterior and posterior ridges are on a distinctly lower level than the middle of the tooth, as is the case in *Dryopithecus*, while in the raised convex median portion there is a faint furrow. I am not, however, inclined to think that either the central ridges or the median cavity were ever so pronounced, as is the case in the Haritalyangar maxilla. There seems to be an approach to the same conformation in pm^4 of the Chimpanzee, though I have not had the opportunity of examining an actual unworn specimen. In the Gorilla we have essentially the same structure, with the important difference that the two folds do not meet in the mid line of the tooth, so that the central cavity are less well defined. A trace of an analogous condition is, however, visible in the hinder ridge of the Haritalyangar premolars, which is bisected by a median furrow. As a whole, in the Gorilla the folds are not thrown into such strong relief as is the case in *Dryopithecus*, due to the successive alternation of continuous ridges and deep hollows. In the Orang the arrangement of the main folds of the premolars is the same as in the present species, but the ridges and the central cavity are less clearly defined, on account of the complicated system of secondary folds and wrinkles, which are absent in the fossil tooth. The breadth of both the premolars is very much behind what obtains in *Palæopithecus* and the Chimpanzee, though this measurement seems to be somewhat variable in the latter; it is in excess of that of the other living apes and Man.

The breadth index of pm^3 in *Dryopithecus* is less than would be the case, were not the length increased by the prolongation of the antero-externalcorner. No anthropoid species has hitherto been discovered, which has its pm^3 extended to such a marked degree at the antero-external angle, so as to be almost triangular in shape.

Such a pm^3 occurs in some of the *Cercopithecidæ*, and an undoubted trace of a similar conformation exists in the Gorilla, and the Orang with even the small ridge on the outer cusp, to which attention has already been called. Pm^3 of *Palæopithecus*, though it has lost the major portion of its crown, is shown by what remains to have had quite a different shape.

The three divergent roots of both the premolars are similar to those of the Orang, Gorilla, and Gibbon. The Chimpanzee has a three rooted pm^3, but its pm^4 has three roots only very occasionally. In Man both premolars have two parallel roots. The premolars of *Palæopithecus* have three roots, but they are more parallel than in *Dryopithecus*.

Isolated upper molars.

The last two specimens, which I have to consider under the head of *Dryopithecus punjabicus*, are Ind. Mus. Nos. D. 186 and D. 187, which were found in the Chinji zone of the Lower Siwaliks near Chinji, without any more exact record of their locality being preserved. No. D. 186 is a 3rd left upper molar and No. D. 187 one of the two left front molars.

Front upper molar.—The dimensions of this tooth are: length 10·0 mm., breadth 10·9, height 5·7, breadth index 109·0. It is figured in Pl. II, fig. 4. Though less worn by attrition during the animal's life than the Haritalyangar molars, it is not so well preserved, but in all essential respects, it resembles them very closely. The cusps are slightly higher, and they slope more steeply towards the centrum, and less steeply on the inner side of the tooth, so that they are rather more pyramidal in shape than in the maxilla. The two ridges, which proceed from the paracone towards the protocone and parallel to the front edge of the tooth, end in a small but distinct cusp, adjacent to and in advance of the protocone. This small cusp recalls that described by Schlosser[1] in an upper molar of *Dryopithecus rhenanus*. No doubt if the Haritalyangar maxilla were less worn a similar cusp would be visible. Even as it is, in certain lights there is a faint trace in the latter specimen of a furrow in this position. The furrows on either side of the connecting crest between the metacone and the protocone are rather deeper than in the Haritalyangar teeth, and the main furrow between the protocone and the hypocone is rather more intense. I do not, however,

[1] Schlosser, l. c., p. 125.

regard the differences as sufficient to prohibit the inclusion of it in the species *Dryopithecus punjabicus*. As its dimensions accord more with those of m^1 in the Haritalyangar maxilla it is probably to be referred to that position in the jaw.

The occurrence of an upper molar in the Chinji area similar to the molars in the maxilla from the Simla region is interesting as affording further testimony in favour of referring the maxilla in question to the same species as the type mandible.

Last upper molar.—The tooth, just described, is also important, for the reason that the features, which I have mentioned above as different from those of the molars in the maxilla, are shared by the isolated m^3 (D. 186), which does not carry on it the hall-mark of identity with the maxilla. Hence any feature, which this m^3 shares in common with D. 187, may be regarded as an argument in favour of assigning the former to the species *Dryopithecus punjabicus*. Still the reference must be regarded as quite provisional.

The tooth, which is represented in Pl. II, fig. 5, is not much worn, but the conditions of fossilization have not been such as to preserve the details of the specimen so well as the maxilla. The cusps are higher than those of the co-type, and more pyramidal in shape, because they slope more abruptly to the centrum and less abruptly towards the base of the crown. Its dimensions are: length 9·6 mm., breadth 11·3, height 5·8, breadth index 117·7. Its antero-posterior, therefore, greatly exceeds its transverse diameter. The latter is greatest at the front of the tooth, and diminishes rapidly backward.

The usual four main cusps of the anthropoid upper molar can be easily distinguished. Of these, the protocone is the largest, the paracone falling slightly behind it in point of size. Both the metacone and hypocone are much reduced. The paracone has a ridge running backward and forward from the summit, and two well marked ones in the direction of the protocone, of which the front one forms the anterior edge of the tooth. Between these two ridges is a deep furrow, similar in character to that in the molars of the Haritalyangar maxilla. Both of these ridges end in a secondary cusp, adjoining and in advance of the protocone. This is more distinct, but similar in character to the one, just referred to in the isolated m^1 in precisely the same position, and recalls the similarly situated cusp described by Schlosser in the upper molar of *Dryopithecus rhenanus*. In the present tooth a furrow runs down the wall of the crown, at the antero-internal corner, between this secondary cusp and the protocone.

The other folds on the paracone and protocone are very obscure. The ridge connecting the metacone with the protocone is cleft by two furrows, both of which are more deeply cut on the side which enters the main valley between the protocone and paracone, thus producing another secondary cusp in the very middle of the tooth. The hypocone is connected with the metacone by a single ridge, forming the posterior edge of the tooth, as in m^2 of the Haritalyangar maxilla, and different from m^1 of the same maxilla, where there is a double ridge. In the present tooth this ridge is cleft by two furrows, which unite into one towards the centrum, to form the valley between the hypocone and the connecting protocone-metacone ridge. These two furrows just cross the edge of the crown, thus producing a third secondary cusp, adjoining the hypocone and behind the metacone. The hypocone contains some additional obscure folds, which end in the main valley between it and the protocone-metacone connecting ridge. This latter valley dichotomizes into two furrows, in precisely the same manner as has been described in the case of the molars of the Haritalyangar maxilla. The foremost of these branches runs up towards the protocone and again dichotomizes, the one of these secondary branches running into the furrow mentioned above, by which the protocone-metacone ridge is cleft, the other running to the inner edge of the tooth which it just crosses. The hindermost of the two branches of the main posterior valley runs vertically down to the base of the crown as a deep furrow, separating the protocone and the hypocone. On either side of this furrow, a cingular connection between the protocone and the hypocone is very distinct, far more so than the similar feature in m^2 of the Haritalyangar maxilla.

Comparing this tooth with the corresponding one of other genera, it differs from Man and *Pithecanthropus* by the much smaller reduction. In both the Chimpanzee and Gorilla, although the reduction of the hinder portion of m^3 seems, as a rule, to be no less than in this tooth, yet that reduction has not affected the metacone much, which is very much larger than it is in the Chinji tooth. This is equally applicable to the m^3 of *Palæopithecus*. M^3 of the Orang approaches this somewhat more nearly in structure, but the complex system of wrinkles in that genus prohibits any very near affinity. From the Gibbon as from *Griphopithecus* it is distinguished by the absence of folding in those genera. The corresponding tooth from Chinji, which has been assigned to the new genus *Palæosimia*, differs from this, both by its exceedingly strong series of wrinkles, and by its inferior breadth index.

In conclusion the intensity and disposition of the folds of this tooth do not agree with any other genus so well as with *Dryopithecus*; moreover, the dimensions, as well as many details of structure, accord with those of the Haritalyangar maxilla and with the Chinji upper molar. I have, therefore, no hesitation in assigning it provisionally to the species *Dryopithecus punjabicus*.

DRYOPITHECUS CHINJIENSIS n. sp.

PLATE II. FIGS. 6, 7.

The type of this species is a last left lower molar, Ind. Mus. D. 179, figured in Pl. II, fig. 6, which was found in the Chinji horizon of the Lower Siwaliks, in the neighbourhood of Chinji, by Sub-Assistant M. Vinayak Rao.

It is with some doubt that I assign this tooth to the genus *Dryopithecus*, since its cusps are rather higher than one would expect, but as its other characters do not seem to ally it to any other genus and are closer to those of *Dryopithecus*, I propose to provisionally place it here.

Its dimensions are as follows: length 14·7 mm., breadth 12·7, height 7·8, breadth index 86·4. The greatest breadth lies in the anterior portion of the tooth, but it hardly begins to diminish appreciably until the hinder third, differing in this respect from *D. punjabicus*. The hypoconid, thus, does not lie internally to the protoconid, but on the other hand the mesoconid is more displaced from the line of the other two external cusps than is the case in the last species: in this respect it recalls *D. rhenanus*. The folding of the enamel is fairly distinct on the internal cusps, but has been largely affected by wear on the external ones. The metaconid is the largest of the cusps, but the other four cusps are approximately equal in size; thus, the entoconid and the hypoconid are larger than in *D. punjabicus*, again showing a greater resemblance to *D. rhenanus*. The cusps slope gently towards the centrum, but more abruptly towards the sides of the tooth, much more abruptly on the internal than on the external side. There is a distinct cingular connection between the protoconid and the hypoconid, situated about half way down the base of the crown, though not quite so broad as in *D. punjabicus*, and the faintest trace of one between the hypoconid and the mesoconid. There is a small secondary cusp between the entoconid and the mesoconid, but it is not possible to say that there is one between the metaconid and the entoconid, although a short furrow on the metaconid indicates a region, which corresponds to the secondary cusp in *D. punjabicus*.

Two parallel ridges connect the protoconid and the metaconid, one along the front edge of the tooth and the other immediately behind it. The cavity between these two ridges is a slight one. Behind this again there are three other folds on the metaconid; the furrow, associated with the middle one of these, just passes over the edge of the crown and produces a serration in side view. Traces of four folds are visible on the entoconid. The furrow, which separates the hinder secondary cusp from the entoconid, is only faintly visible in side view.

The breadth index of this tooth agrees very well with that of *Dryopithecus*, being a little higher than *D. rhenanus* and *punjabicus*, though not so high as in *D. darwini*.

The only other genus with which it might be compared is *Sivapithecus*, with which it agrees in the height of its cusps. The much higher breadth index of m_3 in that genus is sufficient to distinguish it, together with its greater simplicity both as regards folding and general structure of the tooth, the smaller size of the metaconid, and the more backward position of the mesoconid.

It can be distinguished from *Dryopithecus fontani*, in which the cusps are higher than the other species of *Dryopithecus*, by the more inward position of the mesoconid and the smaller cingulum. From this, as well as from every other species of *Dryopithecus* hitherto known, it differs by its greater absolute dimensions.

I have in my collection from the Lower Siwaliks of Chinji two lower molars, (Ind. Mus. Nos. D. 180 and D. 181), of which the former is figured in Plate II, fig. 7, which seem to belong here. They are, obviously, front molars, both on account of their shape and on account of the presence of facets of wear on the hinder as well as the anterior wall of the tooth.

Their dimensions are as follows :—

	D. 180.	D. 181.
Length	11·4	11·7
Breadth	10·0	10·2
Height	6·7	5·2
Breadth index	87·3	87·1

The cusps of the former of these teeth are too high to permit us to assign it to the species *D. punjabicus.* Moreover, its simpler structure, the absence of a cingular shelf between the outer cusps and its higher breadth index militate against the possibility of its being m_2 of that species. Its greater absolute size, apart from the other differences mentioned above, would prevent us from considering it as m_1 of *Dryopithecus punjabicus.*

From its general character and breadth index it might well be the left m_1 of *Dryopithecus chinjiensis.* It is a little smaller than one would perhaps have expected, but the dimensions of m_1 of *Sivapithecus* bear almost the same ratio to those of m_3 as is the case here.

The second tooth is on the right side and is in an extremely advanced stage of wear and beyond the fact that it agrees perfectly in general structure with the last specimen, nothing more can be said about it. It seems to have belonged to a larger individual than the owner of D. 180.

DRYOPITHECUS GIGANTEUS n. sp.

PLATE II. FIG. 8.

The isolated tooth (Ind. Mus. D. 175), figured in Pl. II, fig. 8, was obtained from a bed of cream-coloured, concretionary sandstone on the northern edge of a hill, which is situated close to and north of the small village of Alipur in the eastern part of the Salt Range area on the south-eastern flanks of Diljabba ridge, on the meridian 73° 14′ and is therefore 3 miles north of the map, which accompanied the author's paper on the Correlation of the Siwaliks with Mammal horizons of Europe[1].

It is very near the boundary between the Lower and Middle Siwaliks, but as the typical red concretionary beds of the Chinji zone are well exposed below the bed in which the tooth was found, and as this bed does not differ materially from certain beds of the Middle Siwaliks at Nagri, 10 miles east of Chinji, I have little hesitation in assigning it to the Nagri horizon of the Middle Siwaliks[2].

The specimen is merely the crown of a tooth, without any roots attached thereto. Its dimensions are as follows: length 19·1 mm,

[1] Pilgrim l. c. Pl. 27.
[2] Pilgrim l. c. p. 267, 318.

breadth 15·3, height 8·5, breadth index 80·1. It is, thus, much longer than broad and contains the five typical cusps of the anthropoid lower molar. It does not taper at all within the limits of the two external or the two internal cusps and only very slightly on the external side at the level of the mesoconid. It is thus almost a rectangular tooth. The cusps descend steeply to the base of the crown on the internal side and more gently on the external side. From both sides the descent to the centrum is gradual.

Of the main cusps the metaconid is the largest and highest, the protoconid and hypoconid are about equal in size and height, the entoconid is a little smaller, and the mesoconid is the smallest of all. The general height of the cusps is slightly in excess of what is probably the case in *Dryopithecus punjabicus*, but in defect of *D. chinjiensis*. There is no trace of a cingulum or of a cingular connection between the outer cusps, the furrows between them as between the other main cusps being deep and running right down to the base of the crown.

In its general structure and the nature of the enamel foldings, this tooth can be easily seen to correspond fairly exactly with the species *Dryopithecus punjabicus* and, as far as I can judge, with the other previously described species of that genus. The secondary cusps, which Schlosser has described for *D. rhenanus* and Abel for *D. darwini*, exist in this tooth as what may be described as a series of small cusps or in the case of the hinder, between the mesoconid and the entoconid, as a crenulated ridge. The appearance of this tooth in side view is, in fact, almost identical with the corresponding one in *D. punjabicus*, except that here four crenulations are visible instead of three. This tooth is, no doubt, less affected by wear than those of *D. punjabicus*, and its greater absolute size also tends to make the wrinklings appear stronger than they otherwise would; still there seems no doubt that the folds and furrows, though occupying precisely similar positions to what they do in *D. punjabicus*, are both more numerous and more intense than in the latter species.

The specimen must be the last right lower molar, both because of its shape and the absence of any posterior facet of wear.

It is very considerably larger than any hitherto described species of *Dryopithecus*, but it does not seem possible on that account to separate it from them generically.

Its low breadth index separates it from every other genus except *Neopithecus* and *Pliopithecus*. The m_3 of the former is still more elongated than in my specimen and differs besides by the much weaker cusps and folds. The latter genus differs by the entire absence of wrinkling and by the strong cingulum.

M_3 in the Gorilla, besides being broader, has much higher more isolated cusps, much fewer wrinkles and generally a more simple structure.

By its size alone it can be distinguished from all other species of *Dryopithecus*. It seems to agree more nearly with *D. fontani*, by its rectangular shape, its higher cusps and its crenulated internal edge. The mesoconid in m_3 of that species is, however, more in a line with the protoconid and the hypoconid than in *D. giganteus*, and there is a distinct cingulum in the main type of *D. fontani*.

From *D. darwini* my species differs by its absence of backward taper, and of a cingulum as also by its more elongated shape, the greater frequency of its main foldings and the greater inward displacement of the mesoconid.

The breadth index would seem to approach more nearly that which obtains in *D. rhenanus*, but in that species m_3 tapers more and the mesoconid is more inwardly displaced, while the folds appear to be less numerous than in *D. giganteus*. The sub-triangular shape of *D. punjabicus*, its greater breadth index, its lower cusps and the cingular shelves are the most noteworthy points of difference from *D. giganteus*.

D. chinjiensis differs by its greater breadth index, its higher cusps and its altogether simpler structure.

PALÆOSIMIA RUGOSIDENS n. gen. n. sp.

PLATE II. FIG. 9.

This genus and species is founded upon a last right upper molar (Ind. Mus. D. 188), figured in Plate II, fig. 9, which was obtained from the Chinji zone of the Lower Siwaliks in the neighbourhood of Chinji, though its exact locality is unknown.

Its dimensions are as follows, length 10·8 mm, breadth 11·9, height 6·3, breadth index 110·1. The tooth is broadest in its front portion and diminishes fairly rapidly backward, both inner and outer sides converging at approximately equal angles. The four main cusps of the anthropoid upper molar can be easily distinguished, the largest being the protocone, the paracone falling considerably behind it in point of size ; the metacone is somewhat smaller than the paracone, while the hypocone is much reduced. The crown is but little worn and the sculpture of the surface is perfectly preserved.

It will be most convenient to compare this tooth with the isolated last upper molar (Ind. Mus. No. D. 186), which has been described under the head of *Dryopithecus punjabicus* (p. 23), and I may at once say that the question of referring these two teeth to the same genus has been strongly in my mind, and has caused me a considerable amount of hesitation.

The two anterior transverse ridges, connecting the protocone and the paracone, are present and end in a distinct cusp in advance of the protocone. The front one of these ridges is slightly crenulated. The paracone has five strong folds in addition, and each of these has numerous crenulations across it. The protocone has an additional four, the metacone seven, the hypocone two and all of these have the same cross crenulations. The connecting ridge between the metacone and the protocone is cleft by deep furrows, which separate its median portion as a distinct central cusp even more markedly than in the m^3 of *Dryopithecus punjabicus* referred to above. This also possesses folds both in front and behind. There are two crenulated secondary cusps behind, between the hypocone and the metacone. All the cusps are low, but, in spite of the numerous secondary folds, the main boundaries between them can be distinguished better than in the Orang. The furrow between the protocone and the hypocone only just crosses the edge of the tooth, and is no more pronounced than those between the two hinder secondary cusps or the furrow separating them from the hypocone.

Thus it will be seen that the characteristic feature of the present tooth is the number and intensity of the wrinkles on the enamel surface. In this respect it can only be compared with the Orang among recent or fossil anthropoid genera. It seems to me quite impossible that the m^3 (No. D. 186), referred to above, could have possessed so strong or so numerous wrinkles. The general structure of the two teeth is rather similar, but the same might be said of the Orang, which in regard to the character and arrangement of its folds is nearer to *Dryopithecus* than to any of the living genera. Certain other differences, moreover, seem to support the view that the two teeth belong to generically different animals, and that the present genus was derived from a hypothetical marginal species of

Dryopithecus, perhaps somewhat nearer to *D. darwini* than to the later species, and in any case with characters approximating more nearly to those of the Orang.

These differences are as follows :—

(1) The breadth index of this tooth is very much greater than that of No. D. 186.

(2) The protocone is much larger proportionately, while the metacone is not so reduced.

(3) Corresponding to the reduction of the metacone in *D. punjabicus*, the outer edge of the tooth runs inward much more obliquely than is the case in the present specimen.

(4) The cingular connection between the protocone and the hypocone in *D. punjabicus* is wanting in the present specimen.

(5) The inner edge of this tooth forms a sharp rounded curve extending from front to back, much as in the Orang. This edge of the m^3 of *Dryopithecus punjabicus* is practically straight.

PALÆOPITHECUS SIVALENSIS, Lydekker

1879. *Palæopithecus sivalensis* Lydekker, Further notices of Siwalik Mammalia, *Rec. Geol. Surv. Ind.*, XII, p. 33.

1886. *Troglodytes sivalensis* Lydekker, Indian Tertiary and Post-Tertiary Vertebrata *Pal. Ind*, ser. X, vol. IV, pt. 1, p. 2.

1897. *Palæopithecus sivalensis* Dubois, Ueber drei ausgestorbene Menschenaffen, *Neues Jahrb. f. Min. Geol. u. Pal.* Stuttgart, vol. I, p. 84.

The maxilla, on which the present species was founded, has been described both by Lydekker and Dubois. The latter writer questioned Lydekker's later attribution of the species to the same genus as the Chimpanzee and resuscitated his earlier generic name. I have carefully examined the specimen and remeasured it, with the result that I entirely agree with Dubois as to its claim to generic distinctness. I may add that my measurements of the individual teeth have been made for each tooth separately without regard to its relation to the other teeth in the series; they are taken in the direction which anyone would naturally adopt. supposing they were isolated teeth. In this way they should be more accurately comparable with the numerous anthropoid teeth which are found detached from their mandible or maxilla. The measurements are tabulated, for comparison with other genera, on page 68. I may also remark that all the teeth are so much worn that it seems unfair to base any conclusions either on the apparent lowness of the cusps or the absence of crenulation on the enamel. I should, on the contrary, conclude from the few traces of sculpture still left on the left m^2 and by the general appearance of the teeth that in both of these respects they do not differ at all from *Sivapithecus* and early types of Man. The cusps are, therefore, higher than in most species of *Dryopithecus*, while the folding is probably coarser than it is in that genus, though not so complicated.

The differences of *Palæopithecus* from the Chimpanzee may be summarized as follows:—

(1) The palate is narrower than in the Chimpanzee.

(2) The molars and premolars are broader in proportion to their length; this breadth is especially noticeable in the front portion of the series.

(3) In spite of the breadth of m^3, the degeneracy, as estimated by the disappearance or reduction of the hypocone, is less than in the recent genus.

(4) In *Palæopithecus* both pm^4 and pm^3 are 3-rooted. In the Chimpanzee pm^4 is never 3-rooted and pm^3 only occasionally so.

(5) The height of the cusps is probably greater than in the Chimpanzee.

(6) The crenulation of the enamel is probably much less than in the Chimpanzee, although it is coarser.

(7) The incisors are smaller than in the Chimpanzee.

(8) In pm^4 of *Palæopithecus* the ridges are probably more continuous across the crown of the tooth than in the Chimpanzee.

(9) The canine is larger in *Palæopithecus*.

(10) In *Palæopithecus* the line of the teeth is not convex outwardly as in the Chimpanzee.

(11) The two premolars lie inside the line of the other teeth, and the configuration of the maxilla above them is more like that in Man than the Chimpanzee.

From Man *Palæopithecus* differs in many respects of which some of the most important are the following:—

(1) The narrow palate.

(2) The greatly inferior breadth index of m^2 and m^3 due to the degeneracy of these teeth in Man.

(3) The greater reduction in length of the front portion of the molar-premolar series in *Palæopithecus*.

(4) In Man both the premolars are 2-rooted teeth.

(5) The premolars though broad, are more complicated in *Palæopithecus* than they are in Man.

(6) The much greater size of the canine in *Palæopithecus.*

(7) The more forward position of the incisors in *Palæopithecus* and consequently the much slighter concavity of the front portion of the palate.

Palæopithecus is more nearly allied to *Dryopithecus* than to either Man or the Chimpanzee. Its narrow palate and its small incisors resemble very closely these parts in *Dryopithecus.* Differences from *Dryopithecus* may however be seen in the following particulars:—

(1) The greater breadth index of the molars and premolars, more particularly marked in the front molar and the two premolars.

(2) Probably the cusps in *Palæopithecus* are higher and the folding of the enamel less complicated, though coarser than in most species of *Dryopithecus.*

(3) If the m^3 (Ind. Mus. No. D. 186) is correctly referred to *Dryopithecus* then *Palæopithecus* differs by the greater breadth of the posterior portion of that tooth and by the larger metacone. This tooth is in fact more degenerate in *Dryopithecus.*

Palæopithecus differs from both the Orang and the Gorilla by the large breadth index of the front molar and the two premolars, while the former of these genera can be distinguished by the number and intensity of its enamel folds, and the latter by its high cusps separated by deep furrows.

Differences from the Gibbon may be found in—

(1) The greater breadth of the teeth.

(2) The more complicated although broader premolars.

(3) The absence of wrinkling from the teeth of the Gibbon.

(4) The cusps in *Palæopithecus* are probably higher than in the Gibbon.

(5) The palate in *Palæopithecus* is much narrower.

(6) M^3 in the Gibbon is more degenerate than the corresponding tooth in *Palæopithecus.*

The differences of *Palæopithecus* from *Sivapithecus* will be detailed under the head of the latter genus.

so that the angle included by the two mandibular rami would be larger and therefore the distance between them greater than in any hitherto known genus of anthropoid ape, the structure in fact approaching what we find in Man.

Possibly, though not necessarily, correlated with this structure is another feature of the mandible of the Chinji genus. This is the shortness of the mandibular symphysis. Although the symphysis cannot be actually seen, yet the portion of the ramus left below pm_3 is sufficiently great to make it certain that if the symphysis had extended back as far as in the Orang, the Gorilla, the Chimpanzee or even the Gibbon it would have been evident in our specimen. The inward curvature of the base of the ramus does not begin until a level midway between pm_4 and pm_3 whereas in the living anthropoid apes it begins opposite to m_1, or even behind it, although the curvature is more gradual in the case of the Gibbon than in the others.

When such a condition coexists with a more inward position of the canine, which implies a backward shifting of the entire incisor portion of the jaw, it is evident that the conformation of the symphysis in the genus *Sivapithecus* must have more nearly resembled that of man than of any other of the genera of anthropoids.

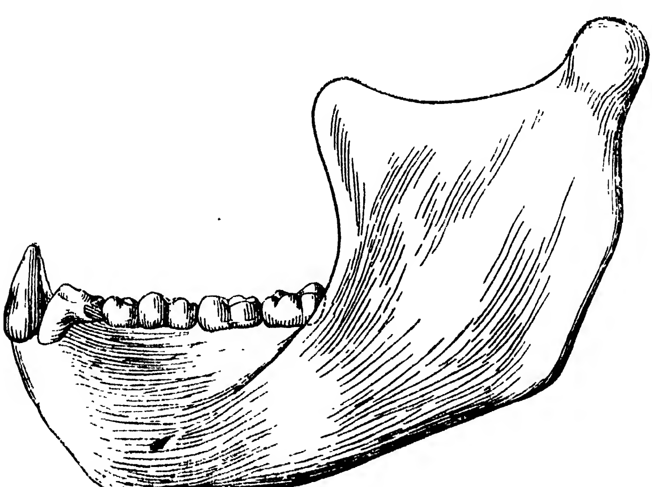

Fig. 1. Ideal restoration of the mandible of Sivapithecus indicus, in left side view; about two-thirds natural size.

An ideal restoration of the mandible of *Sivapithecus* is shown in side and surface view in figs. 1 and 2. It should be clearly understood that this is not intended to represent any specimen, but is merely an attempt to embody the conclusions at which I have arrived after a study of the actual Chinji fragment, considered in the additional light of the two fragments obtained from Haritalyangar, which are described on pages 42 to 46. My conception of the jaw to which the type ramus may have belonged can be conveyed more readily by a pictorial illustration of this kind than by a verbal description. I have, however, no wish to insist on the details of the restoration, which from the fact that the specimens on which it is based do not all belong to the same individual and probably not to the same species, could only by a coincidence be absolutely correct.

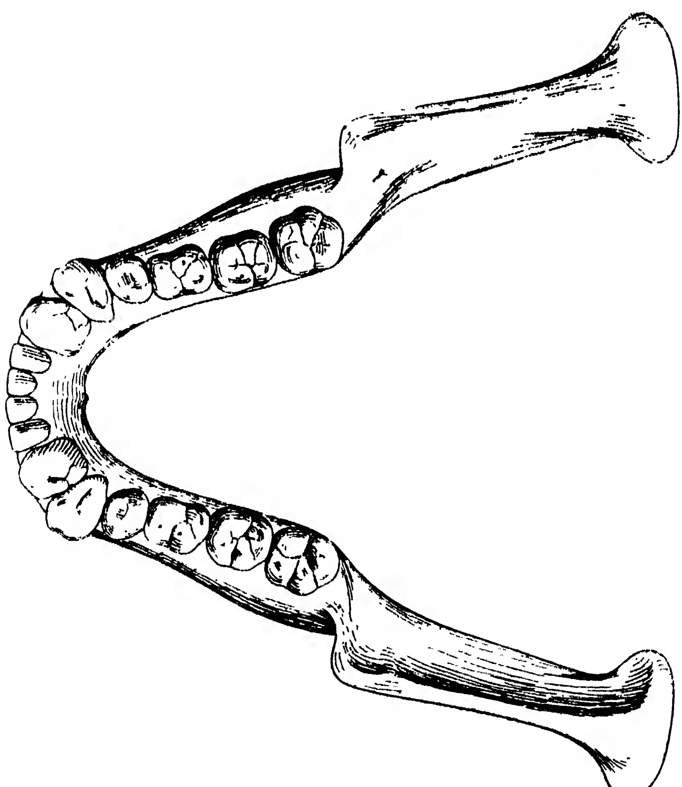

Fig. 2. Ideal restoration of the mandible of Sivapithecus indicus, view from above about two-thirds natural size

The reconstruction of the angle and ascending ramus of the jaw is imaginary. Their size and general structure are mainly based on those of Heidelberg and Chapelle-aux-Saints; indeed one would expect a considerable extent of surface for the attachment of the powerful masticatory muscles which such an animal must have possessed.

In the case of *Dryopithecus* the symphysis is well known to have extended further back than even in the Orang. The symphysis of *Pliopithecus* is equally well known to have extended as far back as m_1. *Palaeopithecus* from its palatal structure is most unlikely to have had a short symphysis.

The symphysis in *Eoanthropus*, as is clearly shown in Smith Woodward's restoration of the Piltdown mandible[1] must, certainly, have been longer than in the Chinji specimen, as the actual symphysis appears to have extended back to the level of the middle of pm_4 while the inward curvature of the ramus began still further back. The actual length of the symphysis in *Eoanthropus* would seem to have exceeded that of the Gibbon, although the inward bending of the ramus begins further back in the latter genus. This abrupt passage of the ramus into the symphysis and the accompanying absence of any sort of shelf internal to m_1 and pm_4 are features shared alike by *Eoanthropus* and *Sivapithecus* and are, no doubt, to be correlated with the greater breadth in the anterior portion of the jaw. The latter character is evidently a later development as it is certainly not primitive. Schlosser considers that the symphysis in *Propliopithecus* probably only extended back as far as the canine.[2] We may, however, gather that the jaw of *Propliopithecus* was extremely narrow in front, as was the case with the better known *Pliopithecus* from the middle Miocene, and therefore presented an entirely different appearance from that of the mandible of *Sivapithecus*.

We may now pass to the structure of the individual teeth.

Last lower molar.—The dimensions of the isolated tooth (Ind. Mus. D. 176), figured in Pl. I, fig. 7, are: length 14·3 mm., breadth 13·4, height 7·3, breadth index 93·7. The dimensions of the m_3 in the type mandible as calculated from the alveolus are length 14·5,

[1] Smith Woodward. Description of a Palæolithic human skull and mandib e, from Piltdown, Sussex. *Quart. Jour. Geol. Soc. Lond.*, vol. LXIX (1903), pp. 133—138.

[2] Schlosser, Beiträge zur Kenntniss der oligocänen Landsäugethiere aus dem Fayum Agypten *Beitr. z. Pal. u. Geol. Öst-Ung.*, Vol. XXIV (1911), p. 52.

breadth 13·4, breadth index 92·4. These are near enough to amount to evidence in favour of the isolated tooth belonging to the same species as the mandible, especially when both exhibit a breadth which is found in the m_3 of no other anthropoid except Man and the Gibbon. The roots in this tooth are not only long and large, but they show no tendency to diverge; on the contrary their great development seems to have led to a certain tendency towards fusion. The surface, though not much worn by attrition, has been corroded in the course of fossilization, so as to obscure the finer sculpture of its surface. The tooth possesses the usual five cusps, of which the hypoconid is the largest; next to this in size comes the metaconid; the protoconid and entoconid are about equal, and the smallest of the five is the mesoconid. The broadest part of the tooth is opposite the hypoconid, thence it narrows slightly in front and rapidly behind. The mesoconid is very considerably displaced to the inside of the line joining the protoconid and hypoconid, thus presenting an appearance entirely different to that of the Gorilla, Orang, *Dryopithecus*, *Pliopithecus* and *Neopithecus*. In Man and the Gibbon the mesoconid is frequently wanting, and in the Chimpanzee is minute, but where, as in some of the lower races of mankind, a 5th cusp is present, then the general aspect of the tooth most resembles that of Man, except for the larger actual dimensions, the main cusps and the furrows being more pronounced than they are either in the Gibbon or the Chimpanzee. Though the details of the tooth are obscure, it is evident that there was a valley in the front of the tooth, just behind and parallel to the anterior edge, and a small cavity behind, between the mesoconid and the entoconid.

Second lower molar.—This tooth is almost a replica of m_3, except for its inferior length and its greater proportionate breadth. Its dimensions are: length 13·0 mm., breadth 12·3, height 7·2, breadth index 94·6. The breadth of the tooth is no greater at the hypoconid than at the front of the tooth and the hypoconid is rather weaker than in m_3. On the internal half of the tooth the ornamentation is fairly distinct, while on the external half the surface has been corroded just as in m_3.

Two parallel ridges unite the protoconid and the metaconid, as is the case in *Dryopithecus*, but the cavity between them is by no means so pronounced as it is in that genus. An additional fold is seen on the protoconid, behind these, running to the centrum, while on the metaconid are some five short coarse folds: the entoconid has also a few short folds. There are no secondary cusps and no cingulum.

First lower molar.—This tooth has suffered more from attrition than the ones behind it, so that even though the entoconid and the hinder portion of the metaconid have escaped corrosion, the furrows which once existed on them have been worn away. Its dimensions are: length 11·5 mm., breadth 10·6, height 6·2, breadth index 92·1. This tooth is thus both shorter and narrower than m_2 or m_3.

Last lower premolar.—The dimensions of this tooth are: length 8·5 mm., breadth 9·9,[1] height 6·5. It has two divergent roots in which respect it differs from the corresponding tooth of Man, which has only a single root, and that of the Chimpanzee, where the two roots are more or less fused. The outline of the tooth forms roughly a parallelogram with a convex outer side. It consists of an inner and an outer cusp, each with a ridge running backward and forward. The cusps are united by three transverse ridges, of which the foremost and the hindermost form respectively the front and back edges of the tooth. The middle ridge is cleft by a furrow. There is nearly twice the distance between the front ridge and the second one as between the second and the third. The hinder ridge also stands at a lower level than the others, the antero-posterior ridges sloping down from the summit of the cusps to meet it.

Alternating with the ridges are two cavities of which the foremost is smaller and shallower than the hinder one. The latter is not only deeper but stands at a lower level than the rest of the crown. A small fold runs into the front cavity from each of the cusps. The hinder ridge and the cavity in front of it may be known as a talon.

This tooth differs markedly by its greater breadth in proportion to its length from the Gorilla, Orang, Gibbon, *Dryopithecus* and *Pliopithecus*. Man does not differ from it so much as the other genera mentioned, but the difference is still marked. The Chimpanzee varies, but its pm_4 has often an extremely high breadth index. The nearest resemblance in structure to pm_4 of *Sivapithecus* is, however, to be found in the corresponding tooth of the Gorilla.

[1] The breadth of pm_4 has been measured at right angles to the axis of the jaw, which at this point bends outward, away from the molar portion. If it were measured at right angles to the axis of the molars the breadth would be 10·4 mm.

The higher breadth index distinguishes *Sivapithecus*, although the recent genus seems subject to some variation in this character. The two inner angles of the tooth in *Sivapithecus* are less rounded than in the Gorilla, and in the recent genus the talon is more pronounced, therein approaching the Orang, Chimpanzee, Gibbon, *Dryopithecus* and *Pliopithecus*. The length of the talon and the corresponding length of the tooth is evidently a primitive condition, which is seen even more plainly in the catarrhine monkeys, in which the talon consists of two distinct cusps. *Sivapithecus*, therefore, shows a distinct approximation to Man.

Front lower premolar.- As this tooth is known only by its alveolus, it is impossible to form very exact conclusions as to its structure. It was of considerable size and two-rooted, the hindermost root being as broad as the posterior root of pm_1 and equally compressed antero-posteriorly. The foremost root is on the contrary compressed transversely and is situated to the outside of the hinder root to the extent of half the long diameter of the latter. The antero-posterior diameter of the tooth as estimated by its roots was approximately 12·6 mm. This tooth thus seems to agree in shape with that of *Dryopithecus* and the Gorilla. The pm_3 in the Orang is rather shorter, and the anterior root is situated further to the outside of the posterior root.

In the Chimpanzee this tooth is smaller in proportion to the rest of the dentition, and the two roots have a tendency to fuse; the anterior root, however, lies less to the outside and its breadth index in this genus is, therefore, lower than in the others. In the Gibbon the anterior root is only slightly displaced to the outside of the posterior one and pm_3 is therefore longer and narrower than in any of the others. In Man, however, the breadth index of pm_3 far exceeds that of any of these other genera and in him alone, moreover, it is one rooted and approximately rectangular.

The lower canine.—This was evidently a large tooth, the diameter of its alveolus being about 10 mm. There is no diastema between it and pm_3 and it lies wholly on the inside of that tooth as mentioned before.

Additional specimens from Haritalyangar.

Since the preceding portion of this paper was written, in fact, when the whole of it had been already sent to press, two additional fragments of a Primate mandible were discovered amongst the material which Sub-Assistant Vinayak Rao collected at Haritalyangar in beds which probably belong to the Nagri zone, and are, therefore, slightly newer than those of Chinji, whence the type mandible of *Sivapithecus indicus* was derived.

There seems little doubt that these belong to the same genus and possibly the same species as the Chinji types, but in that case their owner must have been a slightly larger individual than the latter. It is worth noting as evidence of the absence of bias that before the existence of them was known to me I had provisionally referred a lower m_1 obtained at Haritalyangar to the same species.

Although the recent discovery has hardly necessitated the altering of a single word, yet its importance can not be overestimated, as confirming the conclusions drawn from my examination of the type mandible, and disposing of any objections, which might conceivably have been raised to them on the score of the specimen being pathological or deformed by pressure.

Symphysis.

The first of these additional specimens (Ind. Mus. D. 189) is a portion of the left ramus of the mandible, containing the canine, the roots of two incisors and of the front premolar, and showing the front and back surfaces of the symphysis, being broken at the base 36·5 mm. below the base of the crown of the canine. The correct orientation of the fragment in the horizontal plane is settled by the position of the root of the front incisor, and in the vertical plane by the base of the crown of the canine, apart from the analogy from all other Primates in regard to the direction of the cusp of the canine relative to the horizontal axis of the jaw. In considering the Chinji ramus and the Haritalyangar symphysis as parts of the same mandible, there is a limit to the amount of forward tilt, which can be allowed to the canine in the latter, determined by the position of the canine and the curve of the inner side of the ramus in the former of these two fragments. In constructing the ideal restoration, figured on pages 36 and 37, this limiting value has been chosen. We gather, therefore, that not only was the backward slope of the hinder symphysial surface very slight, with an entire absence of any shelf and passing abruptly back laterally into the body of the jaw, but also that the front surface of the symphysis was almost vertical for a considerable distance. At the very margin of the fragment, there is the slightest indication of a backward curvature. This front surface from the canine to the front incisor is slightly concave both laterally and vertically. The angle between this latter portion and the side of the ramus adjoining pm_3 forms an obtuse angle, considerably removed from the right angle which we find in the anthropoid apes. The approach to a human conformation of this part of the jaw may be realised when it is stated that the anterior root of pm_3, the front half of the canine, and the second incisor are in a straight line, forming an angle of only 20° with the line joining corresponding points on the two rami, as against the curvature of this line in the anthropoid apes, with an approximate average value of 60° for the same angle. There is a prominent foramen in front, near the median line, about 19 mm. below the approximate position of the neck of the first incisor. Such a foramen is occasionally found in the Orang about halfway between the tooth alveoli and the base of the jaw.

On the hinder face of the symphysis about 19·5 mm. below the base of the crowns of the front teeth the surface curves backward slightly towards the median line of the symphysis. In following the surface vertically from above downwards, near the median line it takes a slight bend backwards at the same point, but below this it evidently bends forward again, as can be seen from the surface of the jaw preserved nearer the basal margin but a little to the left of the median line. This would seem to indicate the presence in some degree of a *spina mentalis* in this position, similar to that of modern Man, but in any case a conformation of the hinder face of the symphysis altogether different not only from the apes but also from that of the famous Heidelberg mandible. This is shown in fig. 1 d of Pl. II.

From the above it is evident that the rami must have diverged very considerably, in as great a degree in fact as in Man. The last two molars, as shown by the type mandible, do not lie within the line of the other teeth as they do in man. Consequently the distance between the condyles must have been considerably greater than in any human jaw.

The depth of the symphysis and of the jaw, at all events in its front portion, is, thus, very great in proportion both to the size of the molars and to the united length of the tooth series in the type ramus. This is entirely in accord with the inference drawn from the low position of the mental foramen in the type ramus, with reference to the base of the crowns. This is one of the characters of the mandible of Krapina man, in which this dimension is much in excess of what obtains in other palæolithic types. It is noticeable that Krapina man also agrees with *Sivapithecus* in regard to the distance between the condyles, in which, however, it falls considerably short of the fossil Indian genus.

The stoutness of the jaw, as measured by the ratio of the height at the mental foramen to the thickness at the same point, is rather less than the mandibles of Chapelle-aux-Saints and Heidelberg. The former of these two measurements in the Haritalyangar species can hardly be more than 39 mm. and the latter is about 19 mm., which gives the ratio as 48·7 compared with 52·9 for the Heidelberg jaw, 50 for that of Krapina and 42 for that of a modern negro.[1]

Lower canine.—The lower canine is a conical tooth, having the following dimensions: height of crown 19·0 mm., length 13·9 mm., breadth 10·2 mm. It more nearly resembles the lower canine of the Gibbon than that of any other anthropoid known to me; there is a very distinct indication of a posterior cusp or heel, although the hinder edge of the tooth is so deeply worn by contact with the upper canine that it is impossible to say exactly how prominent this cusp was. The external side of the root, however, exhibits clearly a hollow which is continued up the crown, pointing to the former existence in some ancestral type of a strongly developed hinder cusp on a separate root.

Such a heel is present in the Gorilla, the Orang and the Chimpanzee, but very much feebler than either in the present species or in the Gibbon. In Man it is apparently absent, though even in this case the basal bulge on the internal side of the crown may be a remnant of an original cusp which has been displaced due to lateral shifting of the tooth. A sort of triangular facet is present at the base of the crown internally, the apex of which seems to be prolonged into a narrow ridge running up the crown, although the fracture of the internal upper quarter of the crown does not allow this feature to be followed to the summit. Posteriorly, the upper margin of this facet is continued as a faint cingulum backward and downward to the hinder heel.

Incisors.—These, as shown by their roots, are elongate in a direction parallel to the axis of the jaw and very narrow laterally. The distance from the internal margin of the canine to the median line

[1] These measurements are taken from Boule, L'Homme fossile de la Chapelle-aux-Saints, *Annales de Paléontologie*, vol. VII (1912), p. 82.

measured through the incisors is 13·7 mm. The dimensions of the first incisor are: length 6·6 mm., breadth 3·8 and of the second incisor: length 9·3 mm., breadth 4·7.

Front lower premolar.

The second of the two specimens from Haritalyangar (Ind. Mus D. 190) is a left lower pm_3, the correct orientation of which is clearly proved by the existence of a facet on the inner hinder edge, caused by the contact of pm_4, and by the preservation of the outer portion of the alveolus of the same tooth, while on the antero-internal margin can be seen a part of the alveolus of the canine. The roots, when so placed, correspond identically with those of pm_3 in the type mandible described on page 41, and also, as far as can be judged, with those of the same tooth in the Haritalyangar symphysial fragment.

Thus placed the tooth may be described as being very broad in proportion to its length, with a very convex outer surface passing back gradually, without any abrupt change in the contour, into the straight hinder wall. The inner wall of the tooth forms a very acute angle with the hinder wall and proceeds obliquely towards the outside, where it forms an equally abrupt angle with the outer wall of the tooth, only in this case the angle is a right angle. Thus the actual front wall of the tooth is reduced to the width of a narrow ridge. The main cusp is situated in the centre of the tooth, and is connected by a sloping ridge to a faint secondary cusp directly internal to it, while a second ridge runs from the summit directly forward to the front point of the tooth. On its hinder side the former of these ridges falls abruptly into a hollow bounded by the raised posterior edge of the tooth and on its anterior side equally abruptly into another much smaller hollow just internal to the ridge which runs forward from the summit. A slight cingulum may be present externally, but in any case it is obliterated in the present instance by a strong area of wear at the antero-external corner of the tooth. The structure of this tooth is thus comparable with pm_3 in the Gorilla and the Orang. It differs from them—

(1) by its much greater transverse diameter and corresponding diminution in length,

(2) by the bicuspid character of the transverse ridge.

In respect of the second of these it agrees with the Gibbon and with Man. In the former genus pm_3 is much more elongated antero-posteriorly and is very narrow, while in the latter the breadth index is even greater; further, the tooth is one-rooted, much smaller and more rectangular in shape, the crown is less elevated and the internal cusp much more clearly defined, approximating in size to the main one and separated from it by an almost continuous antero-posterior valley.

Deductions as to upper dentition.

From these two specimens it is possible to deduce some information with regard to the structure of the upper jaw.

It is clear that the wear on the hinder portion of the lower canine and on the antero-external corner of pm_4 are both due to the attrition of the upper canine, which would, therefore, show signs of wear slightly to the inside and to the outside of its front margin, but posteriorly and on the greater portion of its internal side the wear would be *nil*.

This point is of interest as affording an important distinction from the apes, and will be referred to later in discussing the possibility of the maxilla of *Palaeopithecus* belonging to the same genus as *Sivapithecus*.

The upper canine must have bitten slightly inside the lower canine in order to produce this wear, at the same time it must have been situated internally to pm_3, otherwise the upper and lower teeth series would not be in the same line. Moreover, there must have been a considerable amount of lateral movement in the lower jaw, to account for such intense wear in two teeth situated in the position which the lower canine and front premolar of *Sivapithecus* occupy.

Unlike Man, the canines interlocked, which was also the case in *Eoanthropus*. In the latter genus, however, the fact that the upper canine worked wholly on the internal side of the lower canine seems to imply the absence of a diastema in the upper jaw between the canine and the incisors, an inference, which Smith Woodward has in fact drawn in his reconstruction of the upper jaw.[1] On the other hand, it seems equally certain that *Sivapithecus* must have had a diastema in the upper jaw.

[1] See, however, the remark on page 51 below, regarding the possibility that the canine of *Eoanthropus* belongs to the upper dentition. This, if true, may necessitate some revision of Dr. Smith Woodward's view as to the absence of a diastema in the upper jaw.

Lower molar.

A lower molar (Ind. Mus. No. D. 178), which may be referred to the present species, was also found in the same beds at Haritalyangar.

Its dimensions are as follows: length 11·9 mm., breadth 10·9, height 5·9, breadth index 91·6. It is in a very advanced stage of wear but shows the simplicity of structure, the inward displacement of the mesoconid and the absence of a cingulum, which are characteristic of *Sivapithecus*. Its breadth index is nearer to that of the latter genus than to any other, and its dimensions agree fairly well with those of the m_1 in the just described mandible, though it must have belonged to a slightly larger individual.

Upper molars.

A final fragment from Haritalyangar contains the much worn m^1 and m^2. These, though obviously Primate, are, probably, generically indeterminable. Their dimensions in millimetres are as follows :—

M^1	Length	10·5
	Breadth	13·5 (?)
	Breadth index	128·5 (?)
M^2	Length	12·5
	Breadth	14·0
	Breadth index	112·0

The absolute size and breadth index of these teeth agree well with those of the corresponding teeth in the type mandible of *Sivapithecus indicus*. The crown pattern of both teeth is, however, so entirely obliterated by wear and by dental decay that it is impossible to distinguish any similarity of structure to the lower molars of *Sivapithecus*. I should, indeed, be unwilling to deny that they might belong to a species of *Palaeopithecus*, slightly bigger than *Palaeopithecus sivalensis*, although the breadth index of m^1 is much greater than that of the corresponding tooth of *Palaeopithecus sivalensis*, which militates against generic identity.

Upper canine.

The most recent specimen to be discovered, which may be provisionally referred to the genus *Sivapithecus*, is an upper canine, which I found amongst a collection of fossils from the Lower Siwaliks of Chinji. Though apparently Primate, it differs considerably from that of any other genus so far known by the presence of a very distinct cingulum at the postero-internal corner of the tooth. Associated with this is a kind of longitudinal striation, producing a faint crenulated edge to the cingulum, and thence running up a short way in the direction of the summit of the tooth. The cingulum ends in the prominent posterior ridge, which runs up to the summit. There is also an anterior ridge, not so strongly marked. On the inner side of the latter is the usual deep groove seen in Primate upper canines, caused by the abrasion of the lower canine. The two ridges divide the tooth in a vertical plane into two unequal portions, of which the outer is the smaller and has a surface only very slightly convex, while the inner one is the larger and is very strongly convex. The dimensions of this tooth are as follows :—length 16·2 mm., breadth 10·6, height 19·4. The closest parallel to the structure of this tooth is to be seen in the upper canine of the *Cebidæ*. It also is possible that something of the same kind is present in the upper canine of *Pliopithecus*. The cingulum is possibly the remnant of a primitive cusp on its way towards atrophy.

Comparison with other genera.

Considering this mandible as represented by the fragments from Chinji and Haritalyangar, which have been described, there can be no doubt as to its claim to generic distinction. It remains to summarize its affinities with and differences from other Primate genera.

First attention should be called to the great excess of length of m_3 over m_2, the difference being, in fact, greater than in any other genus except *Pliopithecus*. *Dryopithecus punjabicus* does not fall so far behind it in this respect. It is very probable that this is a primitive character.

Although the living anthropoid apes agree with man in the equality or excess of length of m_2 as compared with m_3 yet they differ from him in the relations of length which obtain between m_1 and m_2. In Man m_1 is longer than m_2 whereas in the other genera the reverse is the case. *Sivapithecus* also differs from man in this respect. Considering the breadth index of the various molars, whereas we find that in *Dryopithecus* this increases regularly from m_3 to m_1, in Man and the living anthropoid apes the breadth index of m_2 is greater than that of any of the other molars. *Sivapithecus* agrees with the living genera in this.

Other differences between *Sivapithecus* and *Dryopithecus* are as follows:—

1. The greater breadth of the molars.
2. The simpler structure of the tooth crowns, the absence of secondary cusps, smaller degree of folding and the greater elevation of the main cusps.
3. The greater displacement of the mesoconid to the inside.
4. The short symphysis.
5. The bending outward of the front of the mandible and the consequently greater distance between the rami.
6. The inward position of the canine and the shifting backward of the whole of the incisor portion of the jaw.
7. The greater simplicity and larger breadth index of the last premolar, pm_4.
8. The greater breadth of pm_3 in proportion to its length than is the case in *Dryopithecus*, its bicuspid character, distinct though slight in *Sivapithecus*, and the transverse position of the ridge uniting the two cusps, as contrasted with the oblique direction of the corresponding ridge in *Dryopithecus*.
9. The more vertical front face of the symphysis and its more abrupt passage into the lower margin of the mandible.

The points in which *Sivapithecus* differs from the Gorilla and the Orang are the following:—

1. The greater breadth of the molars.
2. The greater inward displacement of the mesoconid.
3. The short symphysis.
4. The inward position of the canine.
5. The outward bending of the premolar portion of the jaw.
6. The shorter premolars.
7. The more vertical front face of the symphysis and its more abrupt passage into the lower margin of the mandible.

From the Orang it differs in addition by the absence of the characteristic rugosity.

From the Gorilla it differs by—

(1) the much lower cusps.

(2) the bicuspid character of pm_3 and the transverse direction taken by the connecting ridge.

From the Chimpanzee it differs by all the above except 1, and in addition by the higher cusps and the coarser nature of the folding of the enamel.

In certain respects *Sivapithecus* is nearer the Gibbon than it is to any of the other living apes. The chief of these are the short symphysis, which is however shorter than in the Gibbon, the hinder cusp in the lower canine, the bicuspid character of pm_3, the inward position of the mesoconid in the molars. The significance of these special characters common to *Sivapithecus* and the Gibbon, is discussed on page 61.

The differences between the Gibbon and *Sivapithecus* are striking and may be summarized as follows:—

1. The greater breadth of the front molars in *Sivapithecus*. On account of the degeneration of m_3 in the Gibbon, which has not occurred in *Sivapithecus*, that tooth often has a shorter breadth index than is the case in the fossil genus.
2. The much greater length of the premolars in the Gibbon, and the greater height and distinctness of the internal cusp in pm_3.
3. The extreme smoothness of the enamel in the teeth of the Gibbon, and the entire absence of the wrinkling which is to be seen in those of *Sivapithecus*.
4. The outward bending of the premolar portion of the jaw in *Sivapithecus*. This may be correlated with the increased breadth of the jaw.
5. The symphysis is still further shortened in *Sivapithecus*, and there is an entire absence of the shelf, which in the Gibbon lies internal to all the teeth in front of m_2.
6. Thus the rami, instead of coming almost to a point as they do in the Gibbon, pass into a broad rounded margin.
7. The greater depth of the ramus and of the symphysis in *Sivapithecus*.
8. The more vertical position of the front face of the symphysis in *Sivapithecus*.

In all the respects in which *Sivapithecus* differs from the living anthropoids, *Dryopithecus* and *Pliopithecus*, it either resembles Man or makes a decided approach to the conditions which exist in the latter.

In regard to the outward curvature of the premolar portion of the mandible, nothing of the kind is seen in Man, but it certainly seems to me, as has been stated above, that the existence of such a curvature must necessarily be correlated with a greater distance between the rami than exists in any other anthropoid genus than Man. This opinion is confirmed by the examination of the symphysial fragment from Haritalyangar. Agreement with man is shown by the degree of elevation of the cusps, by the nature of the folding, and in the comparative simplicity of structure.

The last two molars in Man, however, generally show a reduction in the number of cusps. Further, the large canine with its posterior heel, the longer pm_3, in which the bicuspid character of the transverse ridge is very much less pronounced, and the greater complication of the premolars generally are not human characters.

The different shape of the mandible in *Eoanthropus* from that of *Sivapithecus* has been mentioned above (page 38). We need not necessarily assume that the restoration of the premolars and of the upper portion of the jaw in advance of the molars is precisely as Smith Woodward has imagined it; it seems quite possible that the premolars may have approximated more nearly in shape and size to those of *Sivapithecus*. In this connection it may be remarked that A. E. Anderson[1] considers that the canine tooth, last discovered at Piltdown, belongs to the upper and not to the lower dentition, as determined by Smith Woodward. If it be an upper canine, then the peculiar condition of wear indicated that the front lower premolar, which caused it, must have been elongate and prominent, in fact much more like the pm_3 of the living apes and of *Sivapithecus*. At the same time it seems certain that there was no outward curvature of the ramus in the premolar region, and probable that the canine lay more in advance of pm_3 than is the case in *Sivapithecus*. The two genera agree in the simple structure of the molars. Their points of difference may be summarized as follows :—

1. The longer symphysis of *Eoanthropus*.
2. The absence of the outward curvature of the premolar region in *Eoanthropus*.

[1] *American Museum Journal*, New York, September 1914.

3. In *Eoanthropus* the canine is smaller and does not possess the posterior heel which is found in the canine of *Sivapithecus*.[1]
4. In *Eoanthropus* the lower canine is probably situated in advance of pm_3 instead of being internal to it as in *Sivapithecus*.
5. The inferior depth of the ramus anteriorly in *Eoanthropus*.
6. The much narrower teeth in *Eoanthropus*.
7. The smaller premolars of *Eoanthropus*, possibly more marked in the case of pm_3.[1]
8. The reduction in length of m_3 as compared with m_2 in *Eoanthropus*. This has not taken place in *Sivapithecus*.
9. The internal wear of the lower canine[1] in *Eoanthropus*, as opposed to the posterior zone of wear in *Sivapithecus*, indicates the absence of a diastema in the former genus between the upper canine and the incisors, in the presence of which *Sivapithecus* probably agreed with the apes.
10. Probably in *Eoanthropus* the front face of the symphysis retreats more than in *Sivapithecus*.

In considering the propriety of referring this mandible to the genus *Palaeopithecus*, we labour under the disadvantage of knowing only the maxilla and upper teeth of the latter genus. Since, however, I am disposed to believe that the height of the cusps and the amount and character of the wrinkling did not materially differ in these two genera, and since in *Palaeopithecus* we find an exceptionally high breadth index for the upper molars just as we do in *Sivapithecus* for the lower ones, it will be as well to mention in detail certain features in the mandible of *Sivapithecus*, which seem incompatible with such a maxilla as *Palaeopithecus* possessed.

1. The outward curvature of the premolar portion of the mandible in *Sivapithecus* could not have been associated with such a maxilla as that of *Palaeopithecus*, as in that case the upper canine would have been opposed to or internal to pm_3, instead of biting outside it.

2. This outward displacement of the premolars in *Sivapithecus*, united with the inward position of the canine, must inevit-

[1] See, however, the above suggestion that this tooth is the upper canine of *Eoanthropus*.

ably have accompanied a backward divergence of the mandibular rami, resulting in a breadth of jaw, which is quite incompatible with the narrow palate of *Palæopithecus*.

3. The inward position of the canine argues a backward shifting of the incisors, so that even supposing the right and left upper tooth series to be parallel as they are in *Palæopithecus*[1] the angle between the upper molar series and the incisor series would more nearly approach a right angle than is the case in *Palæopithecus.*

4. The reduction, which has taken place in the front portion of the cheek teeth series in the maxilla of *Palæopithecus*, is unlikely to have occurred in the maxilla of *Sivapithecus*, judging by the extraordinary dimensions of pm_3 in the mandible of the latter genus.

5. The considerable shortening of the symphysis in *Sivapithecus* from its assumed primitive condition, and the widening of the jaw in the direction followed so markedly in the *Hominidæ*, probably must be correlated with a palate more concave anteriorly than is the case in that of *Palæopithecus*.

6. On page 46, from the observation of the zones of wear on the lower canine and the front premolar from Haritalyangar, considered in connection with the position of the canine with reference to pm_3 and the incisors, I have predicated certain features which might be expected in the maxilla and especially in the upper canine; *Palæopithecus* does not fulfil these, since its upper canine shows a distinct zone of wear posteriorly, such as would be produced by a pm_3 situated immediately behind the lower canine, a position quite at variance with that of the corresponding teeth in the mandible of *Sivapithecus*.

From *Pliopithecus* the present genus is distinguished by its broad molars, by the wrinkling of the enamel, by the absence of the cingulum, by the greater length of the premolars, by the larger canine, and by the short symphysis. It is probable that *Sivapithecus* agreed with it in the backward divergence of the mandibular rami.

Sivapithecus differs from *Propliopithecus* in respect of most of the features which distinguish it from *Pliopithecus*, with the exception of the short symphysis. The molars of *Propliopithecus* are, however, much broader than those of *Pliopithecus*, and in the case of m_1 the breadth index exceeds that of the corresponding tooth of *Sivapithecus*

[1] Such a supposition, unlikely enough before, is now definitely negatived by the discovery of the symphysial fragment from Haritalyangar (Ind. Mus. D 189).

The breadth index of the premolars is less, while pm_3 is a much smaller tooth proportionately to the size of the jaw than in *Sivapithecus*, the canine is much smaller, m_3 shows a reduction in length, and the front of the jaw was probably much narrower.

As *Pithecanthropus* is not known by any portion of the mandible or by lower teeth, no comparison is possible with the Miocene genus. The great degeneracy of the last upper molar and the considerable amount of wrinkling of the enamel, militate against generic identity.

EVOLUTION OF THE ANTHROPOIDEA.

It may not be out of place to discuss the bearing of these new discoveries on the question of the evolution of the Anthropoidea and the relation of Man to the Simian stock.

The remarkable characters possessed by the mandible of *Sivapithecus*, which, as we have seen, ally it in many respects rather to Man than to any of the *Simiidæ*, lead us at once to enquire whether the evidence is strong enough to place *Sivapithecus* on the direct line to the *Hominidæ*.

From the material previously at our disposal it might, I think, be justly concluded that the long and deep symphysis, which is present in all recent apes except the Gibbon and also in *Dryopithecus* and *Pliopithecus*, is a later development from a primitive short and shallow symphysis, such as we find in the lemuroids and many other mammalia and also in the immature mandibles of forms which in the adult stage have long symphyses, implying a descent from ancestors with a short symphysis. The primitively short symphysis is seen in the earliest known member of the Anthropoidea, *Propliopithecus* from the lower Oligocene of the Egyptian Fayum. The extreme shortening of the symphysis seen in Man is as obviously a special development. We may thus conclude with certainty that *Sivapithecus* should take its position somewhere on the main line, from which diverged the cluster of genera which developed a long and deep symphysis, of which *Dryopithecus* is the earliest and perhaps the most typical so far as concerns this particular feature. We have, however, to decide whether the place of *Sivapithecus* on this main line should be before or after this divergence. From the combined evidence of the two mandibular fragments, from Chinji and from Haritalyangar, we may safely conclude that *Sivapithecus* has left the primitive condition and has begun that excessive shortening of the symphysis which is characteristic of Man. This opinion seems to find support in the co-existence of other characters in *Sivapithecus*, which are not found in the *Dryopithecus* to Gorilla line, but which I shall try and show approximate to certain human features.

The outward curvature of the premolar region of the mandible is certainly peculiar to *Sivapithecus*, but, in my opinion, it involves the co-existence of a breadth of jaw and a degree of separation of the mandibular rami which is essentially peculiar to Man. I would suggest that the outward curvature of the premolar portion of the mandible with its accompanying backward shifting of the incisor region was the first attempt to widen the jaw, that the gradual moving outward of the premolar region was succeeded by a corresponding outward movement of the molar region. We, no doubt, have in the present species of *Sivapithecus* a degree of premolar displacement which no ancestor of Man could have possessed, since a displacement of the molars sufficient to bring them into line with the premolars would result in a breadth of jaw far greater than is found in Man. But it may well be that Man has descended from a marginal species of *Sivapithecus*, in which this premolar displacement was less intense. Once begun, as seems to be the case in many other instances, such an adaptation sometimes tends to become exaggerated, but there is no reason to suppose that it became equally exaggerated in every other species of *Sivapithecus*.

With equal or greater justice it might be contended that the short bicuspid pm_3 of Man could not have been evolved out of the pm_3 of *Sivapithecus*, where the internal cusp is no more than a slight prominence on a transverse ridge sloping downward internally from the summit. If, however, we are willing to admit that the bicuspid character of pm_3 is a later development from a primitively unicuspid tooth, there should be nothing discordant in the fact that a sarmatian ancestor of Man does not show the bicuspid structure as plainly as his more modern descendants. Indeed, if both the cusps in the pm_3 of *Sivapithecus* were rather lower and the inner one were a little farther removed from the main one, it would be little different in essential features from that of Man. A species possessing such a pm_3 might easily be included in the genus *Sivapithecus*, and then an inward movement of the external face of the tooth and especially of the antero-external angle, accompanied by a general diminution in size of the whole tooth and atrophy of the anterior root would lead to a type identical with that of modern Man.

Amongst the teeth of Krapina man, figured by Gorjanovic-Kramberger[1], is a pm_3 which shows a very decided approach to the hypothetical condition described above. That specimen is triangular in shape, is strongly developed on the external side, and the inner and outer cusps are connected by a ridge, which is not only prominent but also oblique.

That the front premolar in the Primates was originally unicuspid, may be conjectured from the fact that the modern representatives of the more primitive family of the *Cercopithecidæ* all possess a single cusp to pm_3. The same is the case in the Lemurs. Further, none of the fossil types show any trace of a second cusp, if we except the vestigial one which Schlosser records in *Propliopithecus.* The latter genus shows evidence in other ways of being on a line which developed precociously in the directions followed by other lines in much more recent times. The Eocene Primates exhibit a very distinct heel in the premolars, but no trace of a cusp internal to the main one. Such an inner cusp is a well marked and fairly constant feature in the Gibbons, but we have no reason to suppose that it dates back from any more remote period than the Pliocene. Slight traces of this second cusp in pm_3 are occasionally met with in the Gorilla, Orang and Chimpanzee.

The *Cebidæ*, it is true, have this inner cusp in pm_3, but in many respects they are an extraordinarily advanced family. Moreover, it must be remembered that in this family there are three lower premolars, and this fact may, for physiological reasons, have led to the early molarization of pm_3.

On the whole, then, it seems that we may consider it possible that the human ancestor might have belonged to the same genus as the mandible of *Sivapithecus indicus.* We must of course be prepared for such a hypothetical Miocene human ancestor, when found, proving to be in the process of evolving a broad jaw by a rather different way, or to be too near Man to make it possible to include it in the genus *Sivapithecus.* In this case *Sivapithecus* would not be on the main line of man's ascent but would represent a special adaptation. For the present, however, I prefer to consider the human ancestor

[1] Gorjanovic-Kramberger, Der diluviale Mensch von Krapina, *Mitt. d. Anthr. Gesells Wien.*, vol. XXXI, p. 190, Pl. III, fig. 3.

as a marginal species of *Sivapithecus*. This is represented in the accompanying table in Plate 4 by the line to Man passing through the end of the name *Sivapithecus* and not through the middle of it.

The characters by which *Sivapithecus* differs from Man and resembles the apes or *Dryopithecus* do not militate in the least against such a view, since these are obviously primitive characters, and there is absolute proof that many of them were but lately acquired by the human stock. Such characters are the large canine, which has been shown to occur even in a genus possessing skull characters so nearly resembling those of Man as *Eoanthropus*. Certain of the primitive Australian races have a slightly larger canine than is the case in normal mankind. The same is true of the Palæolithic species, *Homo neanderthalensis*. Moreover the milk canines of modern Man exhibit amongst the various features, which distinguish them from the permanent canines and which have been detailed by Smith Woodward,[1] that of slightly superior size. The question of the hinder cusp of the lower canine, by which *Sivapithecus* agrees with the apes and especially with the Gibbon and differs from Man is discussed on page 59. It seems likely that this is also a primitive character, and that its gradual atrophy has taken place on more than one line. The chin, which is such a striking feature in the jaw of modern Man, is wanting in some of the more ancient Palæolithic types; hence the fact that *Sivapithecus* does not possess it proves only that that genus is in an early stage of development. The increasing length of the molars as we go backward in the jaw is found in many of the fossil *Hominidæ*, and does not prove any near affinity of *Sivapithecus* to *Dryopithecus*. The recent apes have proceeded along the same lines as regards this reduction in size of the back molars. The loss of the mesoconid in the human m_3 is equally a case of late degeneracy found in the Gibbon and Chimpanzee as well as Man. In Man however this degeneracy has involved m_2 as well as m_3. The large breadth index of the *Sivapithecus* molars as well as its diminution going from m_2 to m_1 may, however, be taken as evidence that *Sivapithecus* has reached a further stage of development than the primitive Dryopithecoid ancestor, hence that the former genus stands on the main line to Man long after the divergence of *Dryopithecus* had taken place.

Stress may also be laid on the resemblance between the molars

[1] Smith Woodward, Supplementary note on the discovery of a palæolithic human skull and mandible at Piltdown. *Quart. Jour. Geol. Soc. Lond.*, Vol. LXX (1914), p. 91.

of *Sivapithecus* and m_1 of Man, which has not degenerated like the two hinder molars. The position of the mesoconid, the general simplicity of structure, the higher cusps, and the coarseness of the folding seem to approximate to similar features in the human stock. The reduction of pm_4 also recalls what has occurred though to a greater degree in Man. The large pm_3 would seem to be a primitive character, judging from the similarly large pm_3 in the *Cercopithecidæ* and the Lemuroids, and by the reduction of the same tooth in the Chimpanzee and the Orang.

A comparison of the mandibles of *Sivapithecus* and *Eoanthropus* seems inevitably to suggest that the latter genus is farther removed than the former from the direct line of human ancestry. The longer symphysis, in which there is certainly no trace of any shortening comparable with that which has taken place in Man, the narrower teeth and the position of the canine, entirely in advance of the premolar series, seem to be primitive characters, which have been retained by the Pleistocene genus *Eoanthropus,* though lost in the Middle Miocene *Sivapithecus.* The human characters of the skull of the former are sufficient reason for assigning it a place on the line of the *Hominidæ.* It necessarily follows that the two lines of *Eoanthropus* and *Sivapithecus* diverged long before the appearance of the latter genus.

The reduction of pm_3, m_3 and possibly of the canine are features of an advanced stage of evolution in the Anthropoidea, such as might be expected in any Pleistocene anthropoid genus quite independently of its particular line of descent.

Before finally deciding the respective claims of these two genera for a position on the direct line to Man, we must investigate the structure of the lower canine, which may tell altogether against the conclusion to which I have so far been leading.

As has been described, the lower canine of *Sivapithecus* seems by the possession of a hinder heel to be more like that of the Gibbon than that of any other of the anthropoids. This prolongation, however, occurs though less strongly in the Orang, the Gorilla and the Chimpanzee. Dr. Smith Woodward seems to imply, though he does not actually state it, that he infers from the fact that the milk canine in the apes does not show this hinder heel so markedly as the permanent canine that the heel is a later development in the race and that primitively the Primates were without it.[1] I hope I have

[1] Smith Woodward. l. c., p. 91.

not misunderstood him, but in any case if this were so, then, obviously' *Sivapithecus* could not have been ancestral to Man, since it would possess a character more advanced than in the latter. I think, however, that Dr. Smith Woodward would be the first to admit that undue stress must not be laid on the milk dentition as evidence of phylogenetic development and more especially on canines. On the other hand such a heel is found in the primitive *Cercopithecidæ* and *Cebidæ*. In *Pliopithecus* it actually takes the form of a basal cusp. Such a structure would be perfectly explainable if we accept the theory[1] that the canine was originally a premolar which has taken on the functions of the former. The heel would then be the remnant of the hinder cusp which is present in the premolars of Primates both primitive as well as advanced, this remnant being largest in the Gibbon, tending to disappear in Gorilla, Orang and Chimpanzee and having entirely vanished in Man. I think therefore that such a canine is what might be expected in a Miocene ancestor of Man.

The obvious conclusion to be drawn from the facts is that *Eoanthropus* represents a collateral stem which did not lead to Man as we know him from any of the recent and most of the fossil types, being, so to speak, only one of Nature's experiments at producing the higher human type. An exception, possibly the only one, to this is seen in the mandible found in the Mauer sands, near Heidelberg, and described by Otto Schœtensack.[2] The symphysis and general structure of this famous relic remind us more of *Eoanthropus* than any other human mandible so far known. Boule suggested, indeed, that the two are specifically inseparable.[3] It has not been suggested, so far as I know, that the Heidelberg jaw should be ascribed to any other genus than *Homo*, but it is believed by many scientists that the species of *Homo*, which it represents, has no connection with modern Man. If my ideas as to the evolution of the anthropoid symphysis are sound, then we seem justified in going farther than this, and placing *Eoanthropus* on the line which led, possibly by degeneration according to Smith Woodward's view,[4] to Neanderthal Man, and *Sivapithecus* on that which led to modern Man.

[1] Compare M. Schlosser, Beiträge zur Kenntniss der oligocänen Landsäugethiere aus dem Fayum: Agypten *Beitr. z. Pal. u. Geol. Öst-Ung.*, Vol. XXIV (1911), p. 52, and see page 64 below.

[2] O. Schœtensack, Der unterkiefer des Homo Heidelbergensis aus den Sanden von Mauer bei Heidelberge. Leipzig, 1908.

[3] M. Boule, L'Homme fossile de la Chapelle-aux-Saints, *Annales de Paléontologie* vol. VIII (1913), p. 246.

[4] Smith Woodward, l. c., p. 139.

After all, when once we have admitted the polyphyletic origin of Man, this hypothesis only places the separation of the two or more branches of humanity rather farther back in the geological record.

A possible alternative to this theory is that *Eoanthropus* stands on the direct line to Man and that the shortening of the symphysis, the increase in width of the jaw, the backward shifting of the canine and incisors, and the broadening of the molars all have taken place since the beginning of the Pleistocene, while *Sivapithecus* is an instance of precociously developed human characters in a Miocene genus, which, nevertheless, evolved no further and did not proceed as far as Man.

On the whole the former of these two views seems preferable, since the period which has elapsed since the Middle Miocene seems ample for some marginal species of *Sivapithecus* to have undergone considerable reduction in regard to its canine, pm_3 and m_3, while, on the contrary, the long symphysis and narrow teeth of the Pleistocene *Eoanthropus* seem as if they could hardly have given rise to Pleistocene forms of *Homo sapiens*, or even of modern Man, in the required time.

There is indeed a third alternative that the human ancestor was on a third line, distinct from that of either *Eoanthropus* or *Sivapithecus*. This, though far from improbable, need not at present be considered as it entirely enters the region of guess work.

Accordingly it is the first of these views which I have tried to express diagrammatically in the table of descent forming Plate 4.

The Gibbon.

The short symphysis of the Gibbon is perhaps closer than that of any other of the living anthropoid apes to what I conceive to be the ancestral form, before its shortening in the *Sivapithecus* line or its lengthening in the *Dryopithecus* line had commenced. The symphysis has, undoubtedly, deepened considerably, and its front edge has become more vertical. It is even conceivable that it may have shortened, but in any case much of its primitive appearance has been retained. When to this we add the narrow palate and mandible, the simple, generally narrow teeth, showing neither cingulum nor crenulation, the elongate crown of pm_3, the strong hinder cusp in the lower canine, not to mention other characters which are not so much in question in the present paper, I see no other probable theory than that the Gibbon is the somewhat advanced representative of an ancient type more nearly allied than the other living apes to the original lemuroid stem, from which the *Sivapithecus*—Man and *Dryopithecus* lines diverged. It seems to me likely that these similar characters in the Gibbon and *Sivapithecus*, which we have good reason to believe are primitive, possess an important significance and indicate a closer connection to one another and to the original anthropoid stock for these two genera than is the case with the other living apes and *Dryopithecus*. Possibly also at an earlier date both the *Cebidæ* and *Cercopithecidæ* separated from the same primitive stock.

Pithecanthropus.

In deciding as to the position which *Pithecanthropus erectus*, Dubois, from Trinil in Java, is to occupy in our genealogical scheme, we are met with numerous difficulties, arising not only from the meagre nature of the material, but also from the doubt whether all of it should be referred to the same species. Assuming that the human features presented by the femur and the skull cap, as well as to a smaller extent by the fragmentary teeth, entitle this genus to rank as one of the *Hominidæ*, it seems to me that we should be quite prepared to find also features which it shares in common with the Gibbon ; these latter features it might owe partially to retention from a primitive gibbonoid ancestor, partially to development along the same lines as the Gibbons ; both of these suppositions are rendered easier, if the belief, which seems to the author so plausible, is accepted, that the human and Gibbon lines are more closely connected than those of other anthropoids. The gibbon-like affinities of *Pithecanthropus* were originally noticed by Dubois, and have later been discussed by other scientists, especially amongst the Germans. More recently Boule has seen in them a strong argument for removing *Pithecanthropus* from the *Hominidæ* and placing it on a special side branch of the *Hylobatidæ*.[1] The human characters of the Javan specimens he would then attribute to convergence. Although I am not prepared to deny this hypothesis, yet in view of the explanation offered above, it seems to me not only unnecessary, but improbable, when one takes into account the dimensions of the Javan remains, which greatly exceed those of the Gibbons, as well as the entire absence of evidence that many of the human characters of the teeth and of the calvarium ever developed on any other anthropoid line than that of Man. I am, therefore, inclined to consider *Pithecanthropus* as an early offshoot from some species of *Sivapithecus*.

[1] M. Boule, l. c., p. 263.

Pliopithecus and Propliopithecus.

Dubois has treated in detail the question of the affinities of *Pliopithecus* and has advanced cogent reasons for not accepting the general view that it is ancestral to the Gibbon[1]. I am in complete agreement with his conclusions. The differences between *Pliopithecus* and the Gibbon may be summarized as follows :—

1. The greater proportionate breadth of the teeth in the front of the jaw in *Pliopithecus*, particularly marked in the case of pm_3, but noticeable in all the premolars, upper as well as lower, and in the first molar above and below.
2. The much longer symphysis in *Pliopithecus.*
3. The greater divergence of the mandibular rami.
4. The unicuspid character of pm_3 in *Pliopithecus*, in contrast to the two cusps which this tooth possesses in the Gibbon.
5. The narrowness of the jaw in front, as shown by the much smaller united breadth of the incisors than in the Gibbon.
6. The much smaller height of the canines in the fossil genus.
7. Whereas in the Gibbon the depth of jaw increases from behind forward, in *Pliopithecus* the depth is uniform.
8. The greater elongation of m_3 in the Gibbon, and the more complicated talon of the same tooth.
9. The greater length of m_3 as compared with m_2 in the Gibbon.
10. The presence of a strong cingulum in the fossil genus which is absent in the Gibbon.

Of these 4 to 10, though, in my opinion, sufficient to justify generic separation, are not incompatible with the supposition, which appears to be generally held, that *Pliopithecus* represents an ancestral type from which the Gibbon directly descended, since we either may be certain or have strong reason to suppose that they are primitive characters : 10 may be primitive, but in any case we are not justified in regarding it as essential. On the other hand it seems impossible to suppose that a genus possessing characters 1 to 3 could have been on the direct line of ancestry of the Gibbon.

With regard to 1, most of the primitive Primate types, except the

[1] Dubois, Ueber drei ausgestorbene Menschenaffen. *Neues Jahrb. f. Min. Geol., u. Pal.*, vol. I. (1897), p. 97.

Cebidæ, possess long premolars, while in the modern anthropoids the length of these teeth is very decidedly less. Moreover such facts as are at our disposal regarding the course of development of the anthropoids, shown for example in the genera which fairly obviously may claim descent from *Dryopithecus* and in the prehuman genera *Eoanthropus* and *Sivapithecus*, lead us to imagine that the tendency has been for the breadth index of the premolars to increase rather than to diminish.

With regard to 2, nothing points otherwise than to the conclusion that such a symphysis as that possessed by *Pliopithecus* is a later development, seen in no single case amongst primitive Primate types.

Additional evidence in favour of the view here advocated is afforded by the Oligocene genus *Propliopithecus* from the Egyptian Fayum. Schlosser has expressed the opinion that this genus is so nearly allied to *Pliopithecus* that it can be regarded as its direct ancestor.[1] There seems to be hardly anything against this. It is, at all events, separated by so great a time interval from *Pliopithecus* that even if it be not its direct ancestor we may yet gather from it the direction of evolution followed in the *Pliopithecus* line. Accordingly we may note the short symphysis and the lesser divergence of the rami of *Propliopithecus* as supplying evidence in favour of the view set forth above.

The extremely large breadth index of all the teeth, but especially of the front premolars, is apparently opposed to it. Equally so, however, would the fact that m_3 is shorter than m_2. There can, however, be no doubt that the latter character is typical of an advanced stage of evolution. Consequently, I am of opinion that the large breadth index in the dentition of *Propliopithecus* is also a precocious development, and points to *Propliopithecus* being an early offshoot from the main *Pliopithecus* line, in which certain features, generally characteristic of a much later stage, have prematurely arisen. It may be observed that features of a precisely similar advanced type occur in the otherwise primitive family of the *Cebidæ*.

The question of the canines in this branch merits consideration. Are the small canines in *Propliopithecus* an instance of precocious reduction, similar to what has occurred at an extremely recent period in the case of the *Hominidæ*, or were the canines of the

[1] Schlosser, l. c., p. 54.

Anthropoidea primitively small? The answer to this can only be hazarded as a guess. One is, however, inclined to presume that the reduction of the canines in Man is too recent to be regarded as other than a physiological adaptation, associated with his upward progress towards civilization and possibly adoption of tools. Further the milk canine in the anthropoid apes tends to be smaller than the permanent canine, just the reverse of the condition observed in the milk canine of Man, which is larger than the permanent canine, suggesting that what occurs in the history of the individual, has also occurred in the history of the race; in each case it is the characters of its more recent ancestors which are reproduced in the milk dentition. Schlosser[1] has suggested that in the Primates generally the canine may have originated as a front premolar which gradually assumed a caniniform shape, the original canine coming to function as an incisor. This transformation is generally believed to have taken place in the Lemuroidea, and such a hypothesis for the *Simiidæ* would explain the small size of the canines in *Propliopithecus*. Even in *Pliopithecus*. which is the next oldest of the Anthropoidea to *Propliopithecus*, the canines are relatively small, but for the most part the various anthropoid lines must by that time have acquired canines of the normal type, assuming that originally they had small ones. Subsequently in the *Hominidæ* alone a recent reduction has occurred.

On this series of facts and deductions therefrom rests my conclusion that *Pliopithecus* cannot be on the main line of ascent to the Gibbon, but must have branched off at a comparatively early date, rapidly specializing on certain lines of its own and on other lines which were to be followed at a much later period by other groups of the anthropoid apes and Man.

The long symphysis, the outward position of the mesoconid and the more complex m_3 equally prohibit us from placing it on the *Sivapithecus* line and make it clear that it must, at all events, have started on the line of development followed more completely by *Dryopithecus*. On the other hand, the increase of the distance between the hinder portions of the two mandibular rami, the entire absence of wrinkling of the enamel and above all the reduction in length of the front portion of the ramus, including the front molar as well as the two premolars—a reduction which in a lower Miocene

[1] Schlosser, l.c., p. 54.

form is especially striking and significant—is entirely opposed to any idea of a long continuance on the *Dryopithecus* line. *Pliopithecus*, then, in my opinion represents an early offshoot from the line of *Dryopithecus* and the recent African apes.

The same arguments, which have been stated above against the theory that *Propliopithecus* was the direct ancestor of *Pliopithecus*, apply equally against assigning to it any position on the lines to the *Gibbon* or to *Sivapithecus* and Man. There remains, therefore, the most probable supposition that it started on an early branch from the *Dryopithecus* line in common with *Pliopithecus*, but separated from the line of the latter genus almost immediately, specializing in the most remarkable way by the broadening of the premolars and the reduction in length of m_3.

Palæopithecus.

Palæopithecus is, unfortunately, known only by the palate and upper teeth. It is, however, evident that its narrow palate points to a primitive condition and, therefore, that the species must either be on the *Dryopithecus* line or be a later representative of a form which was on the main line previous to its division into the *Sivapithecus* and *Dryopithecus* branching. The small size of the incisors in this species is equalled only by that of *Dryopithecus*. Although the structure of the mandibular symphysis is unknown, yet the flatness of the front portion of the palate proves that no shortening of the symphysis, such as has taken place in Man and to a rather less extent in *Sivapithecus*, can have occurred. The most striking difference from *Dryopithecus* consists in the great breadth of the teeth. If this large breadth index were due to reduction from the hinder end of the series, as has taken place in the Orang and the Gorilla, then the first molar should have a smaller breadth index than the second and third. We do not, however, find this to be the case in *Palæopithecus*. Further, m^3 in *Palæopithecus* does not show many signs of advanced degeneration, and m^2 none at all. It would seem, then, that the teeth have broadened without degenerating. The large breadth index of the premolars as well as that of the first molar shows that the shortening has occurred in the anterior portion of the jaw. The condition, in fact, recalls that in *Pliopithecus*; this affinity has already been suggested by Dubois[1], and it certainly seems reasonable to regard *Palæopithecus* as a later and more

[1] Dubois, l.c., p. 96.

advanced representative of a branch, from which *Pliopithecus* had diverged earlier. The vestigial cingulum is reminiscent of *Pliopithecus*, while on the other hand the folding of the enamel and the greater reduction of pm^3 are later developments. Judging by analogy with *Pliopithecus*, it is likely that *Palæopithecus* had an equally long symphysis.

Griphopithecus.

Griphopithecus, known only by the last upper molar, may conjecturally be placed on this line in virtue of its exceptionally large breadth index, unaccompanied by any particular reduction in the number or size of the cusps.

The Gorilla.

The Gorilla bears obvious signs of being descended from *Dryopithecus* by its narrow mandible, its long and deep symphysis, its elongated premolars, and its comparatively low breadth index. It was probably descended from a marginal hypothetical species of *Dryopithecus* with higher cusps and a lesser amount of wrinkling. Evidence for the existence of such a marginal species, may be found in the species *D. giganteus* and *D. chinjiensis*, the latter of which, indeed, might even be the direct ancestor of the Gorilla.

The Chimpanzee.

The Chimpanzee shows a reduction in the upper tooth series, greater than that of any of the other recent genera except Man; this is, however, a later development. The greater degree of wrinkling of the enamel and the lowness of the cusps would suggest that it is not on the same subsidiary branch from *Dryopithecus* as the Gorilla, and the broader mandible and shorter symphysis than *Dryopithecus* inclines me to the opinion that it sprung from an ancestral form, farther back on the main *Dryopithecus* line than the genus *Dryopithecus* itself.

Palæosimia and the Orang.

The existence of a last upper molar at the same horizon as *Dryopithecus*, which has an enamel so crenulated as to bear comparison only with the Orang, inclines us to consider its owner as the ancestor of the Orang. The structure of this tooth admits of a close comparison with *Dryopithecus*, but it is difficult to regard it as generically identical with the latter. It has, therefore, been assigned to a new genus, which has been called *Palæosimia*. The structure of the other teeth and of the mandible in *Dryopithecus* and the Orang are very similar. There are, however, differences in cranial structure from both the Chimpanzee and the Gorilla, which point to a lesser degree of specialization in the Orang. It is necessary, therefore, to consider

Palæosimia as branching off from the *Dryopithecus* line previous to the Chimpanzee and the Gorilla and passing through a marginal hypothetical species of *Dryopithecus.*

Pliohylobates.

Following Dubois[1], the affinities of the femur from the pontian beds of Eppelsheim may be considered to lie rather with the Gibbons, and that author's name for it of *Pliohylobates eppelsheimensis* has an equal right with Pohlig's *Paidopithex rhenanus* to be accepted as the name of the genus and species, since both were published at the same meeting.[2] Dubois' name appears to have attained a certain vogue, while Pohlig's name of *rhenanus* has been employed by Schlosser for a species of *Dryopithecus*, in which the Eppelsheim femur is included by that author. It seems better, therefore, to adopt the name of *Pliohylobates eppelsheimensis* for this specimen, as long as it continues to hold any title to separate generic and specific recognition.

Neopithecus.

As *Neopithecus*, Abel, (*Anthropodus*, Schlosser) is known only by a last lower molar its affinities are very obscure. On account of its low breadth index, and low cusps, accompanied by a folding of the enamel which is certainly less complicated than in *Dryopithecus*, and is no greater than in some early types of Man or in *Pithecanthropus*, I place it provisionally on a branch which left the *Eoanthropus* line at an early date, and has retained many primitive features of the anthropoid stock.

Anthropodus.

Anthropodus, Lapouge[3], being founded solely on an isolated upper incisor and a jugal, is too little known to be included in this phylogenetic survey.

[1] Dubois, l. c., p. 97.

[2] *Société Belge de Géologie, Pal. el Hydrol.* séance du 29th Oct. 1895.

[3] G. de Lapouge. Note sur un nouveau singe pliocène, *Bull. Soc. Scien. et Med. de l' Ouest*, du 4° trimestre 1894. Rennes, p. 202—208.

Table of dimensions and breadth indices of

—		Dryopithecus punjabicus.	Dryopithecus rhenanus.	Palæosimia rugosidens.	Sivapithecus indicus.	Palæopithecus sivalensis.	Pliopithecus antiquus.	Griphopithecus suessi.
M^3	Length	9·6	..	10·8	..	10·4	6·5	..
	Breadth	11·3	..	11·9	..	11·4	7·5	..
	Height	5·8	..	6·3	..	..	..	..
	Breadth Index . .	117·7	..	110·1	..	109·6	115·3	..
M^2	Length	10·6	10·4	..	12·5	12·0	7·0	8·5
	Breadth	11·4	11	..	14·0	13·1	8·0	10
	Height	5·6	4·3	..	..	..	..	..
	Breadth Index . . .	107·5	105·7	..	112·0	109·1	114·2	117·6
M^1	Length	10·4	9·6	..	10·5	10·9	6·2	..
	Breadth	11·3	10	..	13·5 (?)	12·5	7·4	..
	Height	5·3	7	..	..	..	..	..
	Breadth Index . . .	108·6	104·1	..	128·5 (?)	114·7	110·9	..
Pm^4	Length	6·6	..	..	..	7·5	4·5	..
	Breadth	9·7	..	..	..	11·8	7·0	..
	Height	5·5	..	..	..	..	..	..
	Breadth Index . . .	146·9	..	..	..	157·3	155·5	..
Pm^3	Length	7·0	..	..	..	..	4·5	..
	Breadth	9·5	..	..	..	..	6·0	..
	Height	6·2	..	..	..	..	..	..
	Breadth Index . .	135·7	..	..	..	..	133·3	..

anthropoid upper molars and premolars.

—		Simia satyrus.	Gorilla savagei.	Hylobates leuciscus.	Hylobates agilis.	Anthropopithecus niger.	Pithecanthropus erectus.	Man.
M^3	Length	12·6	14	5·2	4·5	9·7	11·3	8·6
	Breadth	14·8	15·7	6	5·2	10·9	15·3	10·6
	Height	..	..	..	..	..	..	6·3
	Breadth Index	117·5	112·1	115·4	115·5	112·4	135·3	123·3
M^2	Length	14·0	16·7	6·5	6·5	11·0	12·0	9·2
	Breadth	15·8	16·6	7·1	6·4	11·4	14·0	11·5
	Height	..	..	..	..	..	..	7·2
	Breadth Index	112·9	99·4	109	98·4	103·6	116·6	125
M^1	Length	14·7	14·8	6·1	6·5	10·8	..	10·7
	Breadth	14·8	15·4	6·5	6·0	11·4	..	11·8
	Height	..	..	..	..	..	..	7·7
	Breadth Index	100·7	104·2	106·5	92·3	105·5	..	110·3
Pm^4	Length	*10·0	†11·6	4	4	‡6·4	..	6·8
	Breadth	13·1	15·2	5	5	10·3	..	8·8
	Height	9·7	9·7	..	..	..	..	7·5
	Breadth Index	131·0	131·0	125·0	125·0	160·9	..	129·4
Pm^3	Length	11·5	11·7	4	5·0	8·3	..	7·2
	Breadth	12·7	15·5	5	4·5	9·8	..	9·1
	Height	10·5	12·2	..	..	..	..	8·2
	Breadth Index	110·4	132·5	125·0	90·0	118·1	..	126·4

* From a skull in the Indian Museum (No. 4 *b*), the type of *Simia brookei*, Blyth, Jour. As. Soc. Bengal, XXII (1853), Pl. I, II.

† Ind. Mus. No. 184.

‡ Ind. Mus. No. 7587.

Table of dimensions and breadth indices of

—		Dryopithecus punjabicus.	Dryopithecus chinjiensis.	Dryopithecus giganteus.	Dryopithecus fontani (Saint Gaudens).	Dryopithecus fontani (Lérida).	Dryopithecus darwini.	Dryopithecus rhenanus.	Dryopithecus rhenanus.	Eoanthropus dawsoni.
M_3	Length	12·5	14·7	19·1	12·5	11·5	13·5	13·0	11·8	11(?)
	Breadth	10·4	12·7	15·3	10·5	9·5(?)	11·8	10·5	9·8	..
	Height	6·7	7·6	8·5	..	..	5·0	4·0	..	..
	Breadth Index	83·2	86·4	80·1	84·0	82·7	87·4	80·8	83·0	..
M_2	Length	11·6	..	..	12	11	..	10·6	10·0	12
	Breadth	9·9	..	..	10·5	9·5(?)	..	9·2	8·4	10
	Height	5·4	..	..	..	..	..	4·8	..	..
	Breadth Index	85·3	..	..	87·5	86·3	..	86·8	84·0	83·3
M_1	Length	..	..	..	10	10	..	9·5	11·2	11·5
	Breadth	..	..	..	10·5	9(?)	..	8·8	9·5	9·5
	Height	..	..	..	..	..	..	4·0	..	..
	Breadth Index	..	..	..	105	90	..	92·6	84·8	82·6
Pm_4	Length	..	..	..	9	..	..	..	..	..
	Breadth	..	..	..	8	..	..	..	..	..
	Height	..	..	..	..	..	..	..	..	..
	Breadth Index	..	..	..	88·8	..	..	..	..	..
Pm_3	Length	..	..	..	10	..	..	..	..	..
	Breadth	..	..	..	8	..	..	..	..	..
	Height	..	..	..	..	..	..	..	..	..
	Breadth Index	..	..	..	80·0	..	..	..	..	..

anthropoid lower molars and premolars.

—		Sivapithecus indicus.	Pliopithecus antiquus.	Propliopithecus hæckeli.	Neopithecus brancoi.	Simia satyrus.	Gorilla savagei.	Hylobates leuciscus.	Hylobates agilis.	Anthropopithecus niger.	Man.
M_3	Length	14·3	7·5	5·3	10·3	14·6	16·2	5·9	5·5	11·6	10·7
	Breadth	13·4	6·0	4·5	7·8	12·8	14·0	5·2	6·0	10·0	9·8
	Height	7·3	..	2·8	5·3	..	..	..	..	..	8·7
	Breadth Index	93·7	80·0	81·9	75·7	87·7	86·4	88·1	109·0	86·2	91·6
M_2	Length	13·0	7·3	5·5	..	15·5	16·0	6·7	6·8	12·0	10·7
	Breadth	12·3	6·0	5	..	13·9	14·6	5·6	6·0	11·2	10·1
	Height	7·2	..	3	..	..	..	..	..	..	6·9
	Breadth Index	94·6	82·2	90·9	..	90·0	91·3	83·6	88·2	93·3	94·4
M_1	Length	11·5	6·2	5·2	..	12·8	15·3	6	6·5	11·4	11·2
	Breadth	10·6	5·5	5	..	11·8	13·5	5	5·5	10·3	10·3
	Height	6·2	..	3·2	..	..	..	..	..	..	7·7
	Breadth Index	92·1	88·7	96·1	..	92·2	88·2	83·3	84·0	90·3	92
Pm_4	Length	8·5	5·0	4	..	10·3	†11·7	4	5·5	‡6·9	7·1
	Breadth	9·9	5·0	4·2	..	10·5	12·4	4	4·0	8·7	8·0
	Height	6·5	..	3·5	..	..	..	..	..	..	7·9
	Breadth Index	116·5	100·0	105·0	..	102·0	105·9	100	72·7	126·1	112·7
Pm_3	Length	12·8	6·0	4	..	10·4	13·4	5·8	7·0	9·2	6·9
	Breadth	14·1	4·5	4	..	10·8	13·0	4·0	4·0	7·9	7·7
	Height	..	..	4	..	..	..	..	..	..	7·8
	Breadth Index	110·1	75·0	100·0	..	103·8	97·0	68·9	57·1	85·8	111·6

† Ind. Mus. No. 184.
‡ Ind. Mus. No. 7587.

Table of ratios of lengths of last two Molars of Anthropoids.

—	$\frac{\text{Length of } m_3 \times 100}{\text{Length of } m_2}$	$\frac{\text{Length of } m^3 \times 100}{\text{Length of } m^2}$
Dryopithecus punjabicus	107·7	90·6(?)
Dryopithecus fontani (Saint Gaudens)	104·1	..
Dryopithecus fontani (Lérida)	104·5	..
Sivapithecus indicus	110·0	..
Palæopithecus sivalensis	..	86·6
Propliopithecus haeckeli	96·4	..
Pliopithecus antiquus	110·1	92·8
Simia satyrus	94·2	90·0
Gorilla savagei	101·2	83·8
Hylobates leuciscus	88·1	80·0
Hylobates agilis	80·9	69·2
Anthropopithecus niger	96·7	..
Eoanthropus dawsoni	91·7 (?)	..
Man	100·0	93·5

EXPLANATION OF PLATES.

PLATE I.

FIG. 1.—*Cercopithecus* (?) *asnoti* Pilg. right maxilla with m^1 and $mm.^4$ 1 side view, 1a surface view ×2. From the Middle Siwaliks of Hasnot, Punjab (Ind. Mus. D. 12) Page 3

FIG. 2.—*Cercopithecus* (?) *asnoti* Pilg. last upper premolar developed out of the specimen in fig. 1, 2 side view, 2a surface view ×3.

FIG. 3.—*Cercopithecus* (?) *asnoti* Pilg. left maxilla with mm^3 and mm^4, 3 side view, 3a surface view ×2. From the Middle Siwaliks of Hasnot, Punjab (Ind. Mus. D. 121) Page 4

FIG. 4.—*Macacus* (?) cf. *sivalensis* Lydekker right mandibular ramus with m_1 and m_2 4 side view, 4a surface view ×3. Form the Middle Siwaliks of Hasnot, Punjab (Ind. Mus. D. 184) Page 6

FIG. 5.—*Dryopithecus punjabicus* Pilg. right mandibular ramus with m_3 and the broken m_2 5 surface view, 5a side view, natural size, 5b m_3 in the same specimen ×3. From the Lower Siwaliks of Chinji, Salt Range (Ind. Mus. D. 118) Page 9

FIG. 6.—*Dryopithecus punjabicus* Pilg. left mandibular ramus of the same individual with m_2 and the broken m_3, 6 surface view, 6a side view of m_2 in this specimen, natural size. From the Lower Siwaliks of Chinji (Ind. Mus. D. 119) Page 9

FIG. 7.—*Sivapithecus indicus* Pilg. last right lower molar, surface view, natural size. From the Lower Siwaliks of Chinji (Ind. Mus. D. 176) Page 39

FIG. 8.—*Sivapithecus indicus* Pilg. right mandibular ramus with m_2 to pm_4 and the broken m_3 pm_3 and the edge of the alveolus of the canine, 8 surface view, 8a side view from the outside, 8b side view from the inside, natural size, 8c m_2 in the same specimen ×3. [*f*= mental foramen] From the Lower Siwaliks of Chinji (Ind. Mus. D. 177) Page 34

FIG. 9.—*Sivapithecus* cf. *indicus* Pilg. right front lower premolar, 9 surface view, 9a external side view, 9b back view, all figures × 2. From the Nagri zone of Haritalyangar, Belaspur state, Simla Hills. (Ind. Mus. D. 190.) Page 45

PLATE II.

FIG. 1.—*Sivapithecus* cf. *indicus*, Pilg. left half of the mandibular symphysis with the canine and the roots of two incisors and of the front premolar, 1 surface view, 1a front view, 1b back view, 1c outer side view, 1d inner side view, all natural size. [*ar*=front root of pm_3 *pr*=hinder root of pm_3] From the Nagri zone at Haritalyangar, Belaspur state, Simla Hills. (Ind. Mus. D. 189.) Page 42

FIG. 2.—*Sivapithecus indicus* (?) left maxilla with two front molars, surface view natural size, from the Nagri zone of Haritalyangar, Belaspur state, Simla Hills. (Ind. Mus. D. 191.) Page 47

FIG. 3.—*Sivapithecus indicus*, (?) left upper canine, 3 external view, 3a front view, 3b back view, 3c internal view, all natural size, from the Lower Siwaliks of Chinji. (Ind. Mus. D. 192) Page 47

FIG. 4.—*Dryopithecus punjabicus* Pilg. left front upper molar, surface view ×3. From the Lower Siwaliks of Chinji. (Ind. Mus. D. 187) Page 22

FIG. 5.—*Dryopithecus cf punjabicus* Pilg. last left upper molar, surface view ×3. From the Lower Siwaliks of Chinji. (Ind. Mus. D. 186) Page 23

FIG. 6.—*Dryopithecus chinjiensis* n. sp. last left lower molar, surface view natural size. From the Lower Siwaliks of Chinji (Ind. Mus. D. 179). Page 25

FIG. 7.—*Dryopithecus chinjiensis* n. sp. first left lower molar, surface view natural size. From the Lower Siwaliks of Chinji (Ind. Mus. D. 180) Page 26

FIG. 8.—Dryopithecus giganteus n. sp. last right lower molar, surface view ×2. From the base of the Middle Siwaliks near Alipur, Bakrala ridge (Ind. Mus. D. 175) Page 27

FIG. 9.—*Palæosimia rugosidens* n. gen. n. sp. last right upper molar, surface view ×3. From the Lower Siwaliks of Chinji. (Ind. Mus. D. 188) Page 29

PLATE III.

FIG. 1.—*Dryopithecus punjabicus* Pilg. right maxilla with m_2, m_1, pm_4 and pm_3, surface view ×3. From the Nagri horizon of the Middle Siwaliks at Hari Talyangar, Belaspur state, Simla Hills. (Ind. Mus. D. 185) Page 16

FIG. 2.—*Dryopithecus punjabicus*, Pilg. same maxilla, side view ×3.

PLATE IV.

TABLE showing the suggested evolution of the Anthropoid apes and Man.

THE BRACHIOPODA OF THE NAMYAU BEDS OF BURMA: PRELIMINARY NOTICE BY S. S. BUCKMAN, F.G.S.

THE *Brachiopoda* from the Namyau Beds belong to the families *Rhynchonellidæ* and *Terebratulidæ*, the number of specimens of the former greatly predominating. At first sight the material appeared to be unsatisfactory and uninteresting; but closer investigation showed that the specimens were certainly of considerable interest, though many were in a somewhat unsatisfactory condition from crushing.

It happened that the specimens had with few exceptions been burnt: thus their tests flaked off and exposed to view certain internal details, such as muscle-marks, dental plates, etc. Then it became obvious that it was necessary to burn known species for comparison. As the burning proceeded it was seen that the investigation was by no means a simple one; but that the results obtained were furnishing most important data both for a classification of the families concerned and for ascertaining dates of species of unknown age.

It soon became evident that the Namyau *Brachiopoda* were from strata of Jurassic age, and that a classification of the Jurassic *Rhynchonellidæ* and *Terebratulidæ* would be necessary to explain their affinities. The following is an outline of the classification projected.

Family, RHYNCHONELLIDÆ.

The *Rhynchonellidæ* are divisible into three main series—*Læves*, *Capillatæ*, *Ornatæ*. *Læves* are smooth and develop ribs directly on a smooth stage; *Capillatæ* have hair-like lines (striæ) and then may develop ribs; and *Ornatæ* have additional ornament, like imbrication, or spines.

The type of *Rhynchonella, R. loxia*, Fischer, is one of the *Capillatæ*. The *acuta* group, which so much resembles it, belongs to the *Læves*, and so must be removed. The result is that *Rhynchonella*, which once covered hundreds of species from Ordovician to Recent, must now be confined, so far as present knowledge goes, to one species, *R. loxia*. Cretaceous developments may be looked for; but many Cretaceous species belong to *Cyclothyris*, M'Coy, distinguished by obsolete or obsolescent dorsal septum and broad dorsal muscle-scars.

Genera.[1]	Genotypes.[2]	REMARKS.
	LÆVES.	
* *Pisirhynchia*	*R. pisoides*, Zittel	
* *Holcorhynchia*	*R. standishensis*, S. Buckm.	
* *Gnathorhynchia*	*G. liostraca*, S. Buckm. sp.	
* *Calcirhynchia*	*C. calcaria*, nov.	*R. calcicosta*, Dav. series
* *Sphenorhynchia*	*S. plicatella*, Sow. sp.	
* *Kallirhynchia*	*K. yaxleyensis*, Dav. sp.	
* *Tropiorhynchia*	*T. thalia*, d'Orb. sp.	
* *Piarorhynchia*	*P. radstockensis*, Dav. sp.	
* *Cuneirhynchia*	*C. dalmasi*, Dum. sp.	
* *Curtirhynchia*	*C. oolitica*, Dav. sp.	
* *Homœorhynchia*	*H. acuta*, Sow. sp.	
* *Rhynchonelloidea*	*R. ruthenensis*, Reynès sp.	
* *Costirhynchia*	*C. costigera*, nov.	*R. subringens*, Dav. series
* *Grandirhynchia*	*G. grandis*, nov.	
* *Tetrarhynchia*	*T. tetraedra*, Sow. sp.	
* *Quadratirhynchia*	*Q. quadrata*, nov.	
* *Gibbirhynchia*	*G. gibbosa*, nov.	*R. amalthei*, Dav. series
* *Rudirhynchia*	*R. rudis*, nov.	*T. calcicosta*, Quen. series
* *Stolmorhynchia*	*S. stolidota*, nov.	
* *Ptyctorhynchia*	*P. pentaptycta*, S. Buckm. sp.	
	LÆVES ?	
* *Globirhynchia*	*G. subobsoleta*, Dav. sp.	
Burmirhynchia	*B. gutta*, nov.	

[1] Names with asterisk were proposed in a leaflet "Gen. of some Jurassic Brachiopoda," published by Messrs. Wesley & Son, London, June, 1914. Names in heavy type are new.

[2] Genotypes are written with sp. to denote that the species to be subsequently figured in the memoir in the Palæontologia Indica will be the actual types, in case of questions of misidentification.

Genera.	Genotypes.	REMARKS.
	LÆVES ?	
* *Rhactorhynchia*	*R. rhacta*, nov.	*R. subtetrahedra*, Dav. and *R. obsoleta*, Dav. series
* *Goniorhynchia*	*G. goniæa*, nov.	*R. boueti*, Dav. series
* *Russirhynchia*	*R. fischeri*, Rouillier sp.	
* *Cymatorhynchia*	*C. cymatophorina*, S. Buckm. sp.	
* *Kutchirhynchia*	*K. kutchensis*, Kitchin sp	
	CAPILLATÆ.	
* *Maxillirhynchia*	*M. implicata*, nov.	
* *Parvirhynchia*	*P. parvula*, Desl. sp.	
Rhynchonella, Fisch.	*R. loxia*, Fischer	
* *Trichorhynchia*	*R. deslongchampsi*, Dav.	
* *Capillirhynchia*	*C. wrighti*, Dav. sp.	*R. furcillata*, Dav. series
* *Furcirhynchia*	*F. furcata*, nov.	
* *Lineirhynchia*	*L. cotteswoldiæ*, Upton sp.	
	CAPILLATÆ ?	
* *Rimirhynchia*	*R. rimosiformis*, nov.	*R. rimosa*, Dav. series
* *Prionorhynchia*	*P. serrata*, Sow. sp.	
	ORNATÆ.	
* *Squamirhynchia*	*S. squamiplex*, Quen. sp.	
* *Flabellirhynchia*	*F. lycetti*, Dav. sp.	
* *Granulirhynchia*	*G. granulata*, Upton. sp.	
* *Cryptorhynchia*	*C. pulcherrima*, Kitchin sp.	
* *Nannirhynchia*	*N. subpygmæa*, Walker MS.	*R. pygmæa*, Dav. series
* *Striirhynchia*	*S. dorsetensis*, S. Buckm. sp.	
* *Acanthorhynchia*	*A. panacanthina*, B. & W. sp.	
Acanthothiris, d'Orb.	*A. spinosa*, d'Orb. sp.	

Family, TEREBRATULIDÆ.

These are divisible like the *Rhynchonellidæ* into *Læves*, *Capillatæ* and *Ornatæ*, with the advantage that there are no *Læves* or

Capillatæ of doubtful origin, because the prior stage has not, as with several *Rhynchonellidæ*, been obscured by development of multiplication.

In addition to these groups it has been convenient to make one of *Rugosæ*, for species with strong transverse ornament.

Genera.	Genotypes.	REMARKS.
	LÆVES.	
Orthotoma, Quenst.		
Pseudoglossothyris, S. Buckm.		
* *Linguithyris*	*L. bifida*, Rothp. sp.	
Nucleata, Quenst.		*Glossothyris*, Douvillé
Antinomia, Cat.		
Pygope, Link		
Pygites, Haan		
Euidothyris	*E.* aff. *euides*, S. Buckm. sp.	
* *Ptyctothyris*	*P. stephani*, Dav. sp.	
Heimia, Haas.		
Charltonithyris	*C. uptoni*, S. Buckm. sp.	
* *Lobothyris*	*L. punctata*, Sow. sp.	
* *Cererithyris*	*C. intermedia*, Sow. sp.	
Stiphrothyris	*S. tumida*, Dav. sp.	*T. globata*, Auctt.
Stroudithyris	*S. pisolithica*, S. Buckm. sp.	
* *Loboidothyris*	*L. perovalis*, Dav. sp.	
Kutchithyris	*K. acutiplicata*, Kitchin sp.	
* *Lophrothyris*	*L. etheridgii*, Dav. sp.	
Tubithyris	*T. wrighti*, Dav. sp.	
* *Sphæroidothyris*	*S. sphæroidalis*, Auctt. sp.	
* *Goniothyris*	*G. gravida*, Szajn. sp.	
Epithyris, Phillips		
Plectothyris	*P. fimbria*, Sow. sp.	
* *Plectoidothyris*	*P. polyplecta*, S. Buckm. sp.	
Tegulithyris	*T. bentleyi*, Dav. sp.	
	CAPILLATÆ.	
Terebratulina, d'Orb.		
Disculina, Desl.		
Trichothyris	*T. compressa*, Kitchin sp.	
Holcothyris	*H. angulata*, nov.	

Genera.	Genotypes.	REMARKS.
	RUGOSÆ.	
Rugithyris	*R. subomalogaster*, S. Buckm.	
	ORNATÆ.	
Cheniothyris	*C. morieri*, Desl.-Dav. sp.	
Dictyothyris, Douvillé		

In the above classification the genus *Burmirhynchia* is created for the bulk of the Burma *Rhynchonellidæ*; but a few of them may belong to the genus *Sphenorhynchia*—the doubt that exists is owing to the poor condition of the specimens.

The genus *Burmirhynchia* has outwardly some resemblance to the genus *Rhactorhynchia*, of which the Bathian (Great Oolite and Bradford Clay) species have usually been called collectively the *obsoleta*-series: Davidson's identification, however, is certainly incorrect. Internally *Burmirhynchia* differs decidedly from *Rhactorhynchia*. Externally also it bears much resemblance to *Kallirhynchia*, a genus now proposed for what has hitherto been known colloquially as the *concinna*-series, appertaining principally to the Bathian (Cornbrash). Internally there is good distinction.

A further European Bathian (Great Oolite) series, to which *Burmirhynchia* bears a general resemblance, is that of *Rh. hopkinsi*, Davidson. Here, however, there has been some difficulty in obtaining good internal details. But when investigation was extended to various other European Rhynchonellids of the Bathian, loosely grouped under the names *R. obsoleta* or *R. concinna*, it was found that these species showed internal characters agreeing with those of *Burmirhynchia*. It was seen that the burning process, by revealing internal details, afforded what have hitherto been lacking — satisfactory data for the separation of a large body of species of Rhynchonellids of the Bathian,—a mass of species practically unknown to science, because there had been no efficient method of discrimination.

On the evidence of these species the Burma Rhynchonellids are of Bathian (Great Oolite) date, and the Namyau beds are a formation of Great Oolite times, possibly earlier than the Patcham strata of Cutch.

There are about 40 species of *Burmirhynchia* from the Namyau beds, divisible into several series, showing good sequences of development.

The *Terebratulidæ* from the Namyau strata do not give any good evidence for geological date, because they are not comparable with any Jurassic species yet discovered; but in regard to brachiopod evolution they are more interesting than the *Rhynchonellidæ*.

For the Namyau *Terebratulidæ* it has been necessary to make a genus *Holcothyris*; and the name was given because they show the method by which dorsally sulcate species like *Pseudoglossothyris* can develop into biplicates. This is the first lesson which the Namyau *Terebratulidæ* taught, but it has led to a whole series of discoveries. However these Namyau forms are separated from other Jurassic biplicates by the fact of possessing good capillate ornament: this places them in the restricted series of *Terebratulæ capillatæ* in the above classification.

Search for European Jurassic species comparable to *Holcothyris* resulted in a remarkable discovery: that there is in the Bradford Clay of England a whole series of species showing the same sequence of development as the Burma Terebratulids, but they are not capillate, and they therefore take their place among the *Terebratulidæ læves*. But what is also remarkable about them is that they are, with the exception of one small species, *T. bradfordiensis*, Walker-Davidson, wholly new to literature: this shows how little is really known about the geological fauna of a country supposed to be well-explored; and, therefore, no surprise need be felt that the Burma brachiopods are new to science. I found these English species chiefly in the cabinet of Mr. J. W. D. Marshall, but their recognition must be credited to the Burma Terebratulids: they gave the clue.

There are about 20 species of Burma Terebratulids of the genus *Holcothyris*, which can be arranged in several series showing interesting evolutionary changes. The manner in which they have, directly and indirectly, enlarged the field of knowledge with regard to Terebratulid morphogeny can hardly be exaggerated.

It will be noticed that in the above classification certain genera have been founded on species described by Dr. F. L. Kitchin from the Jurassic strata of Cutch.[1] These genera are, among Rhynchonellids, *Kutchirhynchia* and *Cryptorhynchia*, among Terebratulids, *Kutchithyris* and *Trichothyris*. It was necessary, seeing that the Pat-

[1] *Pal. Ind.* (9) III, 1900.

cham beds of Cutch were presumably so nearly of the same date as the Namyau strata of Burma, to investigate the Cutch species; and my cordial thanks are due to Dr. Kitchin for placing specimens at my disposal, as well as for the kind encouragement which he has always so readily given. This Burma investigation has therefore been the means of adding to a knowledge of the Cutch species.

Summary.

The Namyau beds of Burma have yielded about 40 species of Rhynchonellids and about 20 species of Terebratulids, all new to science. The evidence points to these beds being of Bathian age, about the date of the Great Oolite. Between them and the underlying Napeng Beds of Rhætic age there must, therefore, be a nonsequence of some 8 or 9 ages.

The burning of the Namyau brachiopods has suggested a new method of investigation for internal characters, and this has led to a detailed classification of Jurassic *Rhynchonellidæ* and *Terebratulidæ*. This method of investigation must in the future become particularly important, since it affords much surer grounds for discrimination of species.

MISCELLANEOUS NOTE.

Gypsum in Dholpur State.

While I was in Dholpur in November 1913, the Maharaj Rana showed me some small pieces of selenite of local origin, which were being sold in the bazar under the name *ghurdántli hartál*. *Hartál* is the usual Hindustani name for orpiment, sulphide of arsenic, which is used in Indian medicine as a depilatory. Of *ghurdántli* I was unable to get a translation from local informants or from dictionaries, but I suggest that its meaning is "horse-toothed" (Hindi *ghur* horse, and *dántili* toothed) on the analogy of "dog-tooth spar." The selenite was said to be used medicinally, but for what particular purpose in this case I could not ascertain.

The situation of the deposit from which it came is midway between the small villages of Ghuriakhera and Kathumri, about a quarter of a mile from the Chambal river. The latter village only, Kathumri, is indicated on the Indian Atlas (26° 41′, 78° 6′), and lies about eight miles east of Dholpur city.

The occurrence is similar to that in the Hamirpur district, described by La Touche[1] though quite distinct in origin and is probably analogous to the much larger deposits in Jodhpur and Bikanir. The type of country is the same as that in which the Hamirpur gypsum was found, a wilderness of tortuous, deep, and vertical-sided ravines, cut back by monsoon torrents in the kankar-bearing alluvium, the surface of which lies far above the highest flood-level of the Chambal at the present day.

In a small hillock of this nodular alluvium, isolated by denudation, a dark carbonaceous layer, a foot thick, is seen to outcrop horizontally nearly all round the circumference of the hillock at a depth of about thirty feet below its top, but much farther below the uppermost surface of the undissected alluvium. The selenite, in imperfect crystals of a maximum length of 1½ inches, usually considerably less, is scattered sparsely through this dark layer, and is associated with freshwater mollusca of which my colleague Mr. G. H. Tipper has very kindly given the following determination :—

"They are dwarfed forms and do not show any decided evidence for an age older than recent—

Unio sp. allied to *corrugatus* Müller.
Corbicula sp. allied to *occidens* Benson.
Melania tuberculata var.
Vivipara sp.
Succinea sp.
Planorbis sp."

[1] *Rec. Geol. Surv. Ind.*, XXXVII, Pt. 4, pp. 281-5.

Below the gypsiferous bed is a coarse sand, succeeded in turn by normal alluvium, which also overlies the bed to the top of the section. Evidently the gypsum has been deposited during the dessication of a small saline lake. The bed was not traceable into the adjacent masses of alluvium nor does the gypsum occur throughout the stratum.

The occurrence is of no economic importance but is interesting as an example of a mineral unusual in Indian rocks of post-Tertiary age.

A. M. HERON.

RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

Part 2.] 1914. [April

GENERAL REPORT OF THE GEOLOGICAL SURVEY OF INDIA FOR THE YEAR 1914. BY C. S. MIDDLEMISS, B.A., F.G.S., F.A.S.B., *Officiating Director.*

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B

DISPOSITION LIST.

1. During the period under report the Officers of the Department were employed as follows:—

Superintendents.

MR. C. S. MIDDLEMISS .	Returned from leave on the afternoon of the 8th January 1914. At Head-quarters, appointed to officiate as Director, Geological Survey of India, from the 6th April 1914.

MR. E. VREDENBURG .	At head-quarters, engaged on the description of Indian fossils. Placed in charge of Bombay, Central India and Rajputana Party.
DR. L. L. FERMOR .	Returned from leave on the 18th October 1914. Placed in charge of the Central Provinces Party and left for the field on the 5th November 1914.

Assistant Superintendents.

DR. G. E. PILGRIM .	At head-quarters as Palæontologist and in charge of office.
MR. G. H. TIPPER .	Returned from the field on the 14th April 1914. Deputed on the 22nd November 1914 to investigate the building materials at Simla. Returned to head-quarters on the 15th December 1914. Placed in charge of the Burma Party.
MR. H. WALKER . .	Returned from leave on the 24th April 1914. Posted to the Central Provinces Party and left for the field on the 14th November 1914.
DR. E. H. PASCOE .	Returned from the field on the 11th January 1914. Granted privilege leave combined with furlough for 11 months and 3 days with effect from the 29th January 1914. Returned from leave on the 8th December 1914. Deputed to carry out the investigation of the oil-bearing regions of the Punjab and North-West Frontier Province.

MR. K. A. K. HALLOWES — At head-quarters. Deputed on the 11th July 1914 to collect fossil remains in Patiala. Returned to Calcutta on the 18th July 1914. Posted to Central Provinces party and left for the field on the 29th October 1914.

MR. G. DE P. COTTER . — Returned from field on the 28th May 1914. Reposted to the Burma Party and left for the field on the 18th October 1914.

MR. J. COGGIN BROWN — At head-quarters as Curator. Deputed to carry out the geological investigation of the Bawdwin Mines and District. Left for the field on the 1st November 1914.

MR. H. C. JONES . . — Returned from the field on the 20th May 1914. Appointed Curator, Geological Museum and Laboratory, from 1st November 1914.

MR. A. M. HERON . — Returned from the field on the 23rd April 1914. Acted as Lecturer on Geology, College of Science, Poona, from May till September. Reposted to Bombay, Central India and Rajputana Party and left for the field on the 21st October 1914.

DR. MURRAY STUART . — Returned to head-quarters on the 8th July 1914 on termination of the period of his deputation as Professor of Geology at the Presidency College, Madras.

Deputed on the 25th August 1914 to report on certain road metal quarries in Bihar and Orissa. Returned to head-quarters on the 31st August 1914. Posted to Bombay, Central India and Rajputana Party and left for the field on the 21st October 1914.

MR. N. D. DARU . .	Returned to head-quarters on the 16th May 1914. His services permanently transferred for employment in the Indian Educational Service as Professor of Geology at the Madras Presidency College, but on probation for one year with effect from the 23rd June 1914.
MR. H. S. BION . .	Returned from the field on the 23rd April 1914. Deputed to Kashmir for field work from June till October 1914. Reposted to Burma Party and left for the field on the 20th December 1914.
MR. C. S. FOX . .	Returned from the field on the 27th May 1914. Granted privilege leave for 3 months with effect from the 18th September 1914.
MR. R. C. BURTON .	Returned from the field on the 1st May 1914. Deputed to Darjeeling to visit the Happy Valley landslip and surrounding areas for the purpose of making a geological map and to report on the

WAR SERVICES.

6. Mr. C. S. Fox, while absent on privilege leave, was granted a commission in the Royal Engineers, and is at present in training at Aldershot.

Mr. R. W. Palmer, who had remained on the Special Reserve of officers, was recalled to his regiment on the outbreak of war, and, on joining the East Lancashire Regiment, was sent to the front in September. He has already earned great distinction, and has not only been mentioned in despatches but has been awarded the Military cross.

PUBLICATIONS.

7. The publications issued during the year under review comprise one volume of *Records*, four of *Memoirs* and one memoir of *Palæontologia Indica.*

LIBRARY.

8. The additions to the library during the year 1914 amounted to 2,954 volumes, of which 1,161 were acquired by purchase and 1,793 by presentation and exchange.

DRAWING OFFICE.

Increased facilities.

9. Since the rearrangement of the offices in 1912, it has been found possible to bring all the departments of the Drawing office together on one floor. A larger, fully equipped dark-room has been built, and electric arc lamps of high power installed to enable photographic work to be carried on independently of weather conditions.

Halftone and Colour Printing.

10. This better organisation has enabled us to continue on the lines started in 1908, when we began reproducing our own plates by halftone process, and to experiment recently with the production of our geological maps in printed colours, instead of continuing the lengthy and costly process of hand colouring. A first experiment in colour printing has proved entirely successful, as is shown by Plate 10, published in the last volume of these *Records.*

11. This work has been done without the aid of any new appliances and it is hoped that, with a larger printing machine, colour printing can be undertaken on the ordinary 1 inch and ¼ inch=1 mile sheets of the Survey of India.

MUSEUM AND LABORATORY.

Staff.

12. Mr. J. Coggin Brown was Curator of the Museum and Laboratory until the end of October, when he left for Burma, Mr. H. Cecil Jones taking over the duties of Curator. Mr. Ajit Kumar Banerji was Assistant Curator throughout the year. Babu Durga Sankar Bhattacharji continued to work as Museum Assistant, Mineralogical Section, till he was attached to the Central Provinces party for collecting early in November. M. R. Ry. S. Subba Iyer continued to work as Museum Assistant, Palæontological Section, and accompanied Mr. Bion during the summer months to Kashmir for collecting purposes.

Determinative and Chemical work.

13. The number of specimens referred to the Curator for examination and report was 417; of these assays and analyses were made of 40. The above includes the determinations of 76 rock specimens for the Forest Department, Bombay, and the petrological examination of rocks from the Aka and Mikir Hills, Assam. The chemical work included the proximate analyses of 22 samples of coal from the Pakokku District, Burma.

Meteorites.

14. Only one, but a rather large, meteoric fall was recorded during the year. It fell on the 6th April 1914, near the village of Kuttippuram in Ponnani Taluk, Malabar District, Madras. Altogether 11 fragments, aggregating 37,837 grammes in weight were recovered through the Collector of Malabar; three pieces, forming one individual weigh 32,599 grammes. There were also two other additions to the meteorite collection. The first of these is a piece of the Shopian (Shupiyan) meteorite, weighing 305·29 grammes, which fell in Kashmir in 1912. We are much indebted to His Highness the Maharaja of Kashmir for presenting this piece to us. The other, presented by the Mysore Geological Department is a piece weighing 1,109·7 grammes of the Kamsagar meteorite which fell in Mysore in 1902. A description of these meteorites by Mr. J. Coggin Brown will be published in the *Records.* During the year pieces of the Karkh, Chainpur, Khohar and Kuttippuram meteorites were presented to the British Museum; also fragments of Manbhoom and Lodhran meteorites were sent for exchange to Professor G. P. Merrill of the United States National Museum, Washington, who had asked for them for purposes of study. The material in exchange has not yet been received.

New Catalogue of Meteorites.

15. Mr. J. Coggin Brown found time among his other duties to compile a new descriptive list of the collection of meteorites in the care of the Geological Survey, up to August 1st, 1914. This much needed catalogue will be published in the *Records*, and will also appear printed separately for the convenience of arranging exchanges and purchases. If we consider that this collection, as mentioned by Mr. Brown, "is the largest in Asia, and by reason of the number, variety, beauty and rarity of its specimens, one of the most important in the world," we shall appreciate this effort to organise our knowledge of it, which had not been brought up to date since the issue of Mr. T. R. Blyth's appendix to Mr. F. Fedden's catalogue of August 1901.

16. The new features of the present catalogue are the alphabetical arrangement of the material for ready reference, and the adoption of the taxonomic classification of Rose-Tschermak-Brezina, subject to minor modifications by other authorities; a classification which, as stated by the author, though weak in certain features, is yet the best one available, and the one followed in nearly all the great collections of Europe and America. In that classification meteorites are first divided into achondrites, chondrites and siderites. The achondrites are sub-divided into a number of groups characterised by more or less definite mineralogical composition. In the case of the chondrites the subdivisions are based mainly on physical appearance and structure after the separation of the enstatite-anorthite chondrites and the siderolites. The siderites, after the separation of the lithosiderites are grouped into octahedrites, hexahedrites and ataxites, each of which is still further sub-divided. In addition to the work being an elaborate compilation, the verification of much of the material has entailed considerable petrographical research, which has had to be pursued with scrupulous economy in the case of rare falls.

17. In order that this fine collection may continue to grow and worthily represent all Indian meteorite falls, attention may be drawn to the fact that by a Government Resolution, recently reaffirmed, all falls in British India become the property of Government, and should be at once reported to the local authorities and the specimens sent to the Geological Survey Museum.

18. The Geological Survey, by means of portions sent in exchange to all the great collections, and by means of its own display in the

Calcutta Musuem, enables these objects of world-wide interest to be adequately distributed and placed on view for the benefit of everyone.

Donations to Museums, Educational Institutions, etc.

19. As in past years requests were received for specimens of mineral and rocks and duplicate material was presented to the following institutions :—

(1) Cochin Museum.
(2) Prince of Wales College, Jammu.
(3) St. Mary's Convent High School, Naini Tal.
(4) D. J. H. E. School, Sherpur, Bogra.
(5) St. Joseph's High School, Calcutta.

A typical series of charnockite rocks and of Deccan Trap were presented to Dr. H. S. Washington of the Carnegie Institution, Washington. The other donations include uncut agates, etc., from the Deccan Trap, sent to Dr. T. L. Walker, Royal Ontario Museum of Mineralogy, Toronto, Canada, and a specimen of sapphirine-bearing rock presented to Professor A. Lacroix of Paris. A set of specimens illustrating the kodurite and gondite series together with specimens of Indian manganese minerals was sent to the Mysore Geological Department in exchange for the piece of the Kamsagar meteorite presented to the Geological Survey.

Exchanges of Indian minerals and rocks.

20. The following are among the specimens acquired by exchange :—

(1) Fossils and rocks typical of New South Wales with a small type collection of Antarctic rocks, from Professor J. W. Edgeworth David, University of Sydney, New South Wales.
(2) 19 specimens of laterites from Professor A. Lacroix, illustrating his memoir on the laterites of Guinea.
(3) 10 specimens of copper ore, copper-nickel ore, silver-copper ore and gold ore from various localities in the United States and Mexico, from the United States National Museum, Washington.
(4) 25 New Zealand mineral specimens from the Auckland Grammar School, Auckland, New Zealand.
(5) 15 specimens of minerals and alkaline rocks from Mount Royal, Montreal, from the Redpath Museum, McGill University, Montreal, Canada.

New specimens acquired by donation.

21. The following are among the specimens acquired by donation :—

(1) Small rings of gold from Dhalbhum, presented by Mr. Billinghurst.

(2) Native bismuth from Tavoy, Burma, presented by Messrs. Schroder, Smidt & Co.

Mineral Gallery.

22. All the rock cases have now been provided with printed labels, leaving only a few cases with specimens illustrating physical geology, without such labels. It is hoped that by the end of next year all the cases will have printed labels to each specimen. A model of a rig in use in the Burmese oil-fields has been set up in the gallery; and a statue of Buddha made of marble from the Sagyin Hills, Mandalay District, has also been placed there.

Duplicate collections.

23. Babu Bankim Behari Gupta, Field Collector, was employed during the season in collecting various igneous rocks of the Giridih coal-field. These include eurites, granites, diorites, dolerites, mica-apatite-peridotites, norites, anorthosites.

Fossil Invertebrate Gallery.

24. The re-arrangement of the Invertebrate Fossil gallery, which was begun a year ago, is now nearly completed. The final shape of the Permocarboniferous and Tertiary collections, however, awaits the completion of the palæontological examination to which the fossils belonging to these systems are being subjected. For the same reason the labelling of the Tertiary invertebrates remains inadequate.

INDIAN SCIENCE CONGRESS.

25. Under the auspices, and with the co-operation, of the Asiatic Society of Bengal, the inaugural meeting of a Congress under the above title was held in Calcutta in January of the year under report with the object of bringing together those societies and individuals engaged in scientific research in India for mutual co-operation and exchange of ideas, somewhat on the model of the British Association for the Advancement of Science. The meeting was well supported by the Geological Survey, among other well-established scientific bodies. Dr. Hayden was chairman of the section devoted to geology, and papers on geological and allied subjects were contributed by Messrs. Vredenburg and Coggin Brown.

POPULAR MUSEUM LECTURES.

26. One of the series of popular lectures in the Indian Museum, started during the cold-weather of 1913-14, was delivered by Dr. G. E. Pilgrim, on the subject of the Extinct Mammals of India.

GEOLOGICAL SOCIETY AWARD.

27. At the Annual Meeting in February, the President and Council of the Geological Society of London were pleased to bestow the honour of the Lyell Medal on Mr. C. S. Middlemiss, in recognition of his work in advancing the knowledge of the geology of India during a period of service extending over 30 years.

OBITUARY.

Dr. Eduard Suess.

28. I regret to record the death on April 26th, 1914, of the veteran geologist, Dr. Eduard Suess, late Professor of Geology in the University of Vienna. To the younger generation of geologists he will be best known as the author of the monumental work, *Das Antlitz der Erde*, the English translation of which, *The Face of the Earth*, edited by Professor Sollas, has rendered it available to all English-speaking students. To the older past and present members of the Indian Geological Survey Eduard Suess will be much better remembered as the constant friend and helper of the Department, for he had been closely connected with it for nearly 30 years at the time of his retirement from the Chair of Geology in Vienna in 1902.

29. It is only necessary in this note to draw special attention to his labours on our behalf during that time. Privately since the early seventies, and officially since 1886, he had undertaken the care and description of the large Himalayan fossil collections made from time to time by this Department. The sorting, classification, the distribution of them to a devoted band of fellow-workers for description, the supervision of the plates, and the translation of the reports, were all undertaken by him as a labour of love through the above long period; and for this on his retirement, he received the appreciative thanks of the Government of India. It is melancholy to reflect, that the recent outbreak of war, following a few months after his death, has now brought to an abrupt end this long co-operation of our Department with the University of Vienna the details of which were so efficiently organised by Dr. Suess during his life-time.

MINERALOGY AND PETROLOGY.

Hematite from Kajlidongri.

30. Whilst on study leave at Cambridge, Dr. Fermor made a crystallographic investigation of two minerals collected some years ago at the Kajlidongri manganese mine, Jhabua State, Central India. One of these was hematite in small crystals possessing the habit of corundum, the principal faces present being the basal plane (111) and the hexagonal pyramid of the second order $(61\bar{4})$. In addition to these the following forms were identified :—$(51\bar{3})$, $(71\bar{5})$, $(29.1.\overline{27})$*, $(51.1.\overline{49})$* ; (101), (100), (221), and (28.28.13)*—of which the three marked with an asterisk are new forms. Doubtful readings were also obtained for some 9 other pyramids and 7 other rhombohedra, the majority of which would be new forms.

Hollandite from Kajlidongri.

31. The other mineral investigated was hollandite, described, in 1906, as a new species having a composition corresponding to a salt of the acid H_4MnO_5. The crystallographic study proves this mineral to belong to the pyramidal group of the tetragonal system, of which scheelite is the type. The crystals examined, which vary in length from $\frac{1}{8}$ inch to $1\frac{1}{2}$ inches, are tetragonal prisms of the first order (110), with the corners modified by the second order prism (100) and a series of hemihedrally developed ditetragonal prisms, of which the chief is (210). These prisms are terminated by a very flat pyramid taken as (111), modified in one case by the additional form (331). The accepted value of pp'' is 32° 9′, which gives the length of the vertical axis as 0.2880. If it be considered desirable to orient the mineral to show its relationship with scheelite, then the form (111) becomes (105) and the other faces suffer appropriate changes. The value of the vertical axis becomes 1.4400 compared with 1.5356 for scheelite, whilst the value of the angle pp'' for hollandite, which is 32° 9′, is seen to approximate to the angle dd'' of scheelite, which is 34° 9′, d being the form (105) in scheelite. The crystallographic relationship of these two minerals is significant in view of their chemical formulæ, which may be written as R_2MnO_5 and $CaWO_4$ respectively.

The origin of chondrules in meteorites.

32. Whilst at Cambridge Dr. Fermor also made a detailed microscopic study of thin sections of the following Indian meteorites :—Bori, Donga Kohrod, Sindhri, Karkh, Bholghati, Chainpur, Mirzapur, Bilaspur (Baroti), and Khohar, his object being to study the characters of chondrules,

in view of his hypothesis that they represent former garnets. The results of this work have not been entirely as expected and leave unsettled the question of whether the chondrules were once garnets or not. This is due to an unexpected feature which seems to be common to all the meteorites examined and to have escaped previous notice in the literature of the subject. This feature is so unexpected and, if accepted as true, carries with it such obvious difficulties that it is only mentioned with diffidence. Dr. Fermor states that had these thin sections been put before him as slices representing terrestrial ore deposits he would have had no hesitation in affirming that both the minerals, nickel-iron and troilite, had been formed later than the other constituents of the rock and had in many cases reached their present position by a process of metasomatic replacement. Each of these minerals, whilst also occurring with the silicates in the general ground-mass of chondritic meteorites, is often particularly abundant towards the periphery of, but actually within, the chondrules. From a study of the structures of these meteorites it is concluded that many at least of these chondrules consolidated in their present position. There is no evidence to show whether the metallic minerals in the chondrules have been metasomatically introduced from without, or have been taken into solution from the material of the chondrules themselves and re-deposited in the peripheral portion. If the latter alternative could be upheld it would be possible to maintain the garnet hypothesis in an amended form, according to which, instead of supposing that the garnets suffered a dry fusion on release of pressure, water imprisoned in the rock gave the fusion an aqueo-igneous character, so that certain constituents of a chondrule were temporarily taken into solution in water possibly above its critical temperature. One of the meteorites examined, Khohar, contains a great number of chondrules exhibiting polygonal outlines strongly suggestive of a mineral with the symmetry of garnet; whilst in another meteorite, Karkh, one slide showed an obscure patch of a colourless, isotropic, highly refracting mineral, strongly suggestive of garnet itself. Some ten other slides of this fall were cut without the discovery of any further patches of this mineral, so that it has not proved possible to confirm the determination. The presence of unchanged garnet in a chondritic meteorite would place an obvious difficulty in the way of accepting the garnet hypothesis of the origin of the chondrules. One certain point appears to arise from this investigation, namely, that although stony meteorites are not known to carry water, yet at some time in their past history water played an important part; and that changes have taken place within the meteorite since the formation of the chondrules is proved not only by the relationship of the meteoritic minerals to the silicates, but also by the cases, noticed in the Khohar meteorite, for example, in which intergrowth has taken place across the boundary of two chondrules in contact. Of the meteorites examined, all were chondritic except Bholghati and Bilaspur, and of these Bholghati proved to be a rather rare type, namely, a carbonaceous hypersthene-eucrite, analogous to the terrestrial norite; whilst the Bilaspur slide differed from Dr. Prior's description of the fall in being free from chondrules and not breccia-like. Of the chondritic meteorites Karkh contains abundance of an interstitial mineral that is possibly maskelynite, whilst Bori as well as the Bilaspur fall contain what is probably apatite, a mineral but rarely recorded from meteorites.

The origin of calc-gneisses and crystalline limestones.

33. The work now being carried out in the Central Provinces has raised once more the debatable question of the origin of the crystalline limestones, calciphyres and calc-gneisses of India. Professor Judd in 1896 advanced reasons for believing that the crystalline limestones of Upper Burma were chemically formed from pre-existing pyroxenic gneisses.[1]

34. Dr. Fermor, in 1903, when studying the manganese ore deposits of the Chhindwara district, Central Provinces, examined incidentally some of the numerous occurrences of calcareous rocks found in this region, and, in a paper published in 1906[2], advanced the hypothesis that the crystalline limestones of this area have resulted from the chemical alteration of pre-existing rocks containing an abundance of lime and magnesium silicates, and similar to or identical with the calc-gneisses (quartz-pyroxene-gneisses) with which the limestones are associated; the agent by which the alteration was effected being presumably CO_2 in solution. These calc-gneisses are a curious banded series of granulitic rocks constituted of some or all of the following minerals—diopside, hornblende, quartz, labradorite, microcline, epidote, garnet, sphene, zircon, ilmenite, and magnetite, and in special cases scapolite. In spite of the abundant felspar the obviously unusual chemical composition makes it difficult to regard them as formed from an igneous magma. For this reason Dr. Fermor in

[1] *Phil. Trans. Roy. Soc.*, London, Vol. 187 A. p. 205.
[2] *Rec. Geol. Surv. India* XXXIII, pp. 168-171.

1909[1] accepted these rocks as metamorphosed sediments, but still supposed that the crystalline limestones had been derived from the calc-gneisses, and suggested that the CO_2 which caused the change was a portion of that liberated during the conversion of the original impure calcareous sediments into calc-gneisses. The formation of the crystalline limestone was then supposed to be due to reversal of the reaction on alleviation of the pressure conditions. In 1908 Dr. A. W. G. Bleeck[2] in describing the occurrence of rubies in the Kachin hills, Upper Burma, showed that the accessory minerals in the crystalline limestones of that region were probably introduced as the result of the piezo-contact metamorphism of Weinschenk caused by intrusive granite. In 1913 Dr. Fermor during his geological survey of the Chhindwara district was able again to attack this problem in the field and mapped in the neighbourhood of Mohpani (21° 47′ ; 78° 57′) and Nautal (21° 47′ ; 78° 54′) a large number of irregular patches of marble enveloped in ortho-gneiss and torn to shreds by intrusive granites and pegmatites. Where the contact with the enclosing gneisses could be observed thin shells of diopsidic granulite were observed, and this, taken in conjunction with the presence of the fluorine-bearing minerals chondrodite and phlogopite, was regarded as evidence of limited contact metamorphic action produced by the enclosing ortho-gneiss. Later in the same year in a paper read before the 12th International Geological Congress at Toronto[3] Dr. Fermor accepts as a more probable view that the calc-gneisses, calciphyres, and marbles, represent a banded series of calcareous sediments of various degrees of purity ; but at the same time in order to explain numerous cases of replacement of gneisses by calcite he repeats his hypothesis that the CO_2 liberated during the formation of the calciphyres and gneisses may have re-attacked these rocks on release of pressure. In January 1913, W. L. Uglow, in " A review of the existing hypothesis on the origin of the secondary silicate zones at the contacts of intrusives with limestones "[4] initiated a valuable discussion of the merits of the rival hypotheses to explain the formation of the silicate minerals in such metamorphosed calcareous rocks. According to one set of views the formation of these minerals is due to the re-crystallization of the impurities in the original sediments with later introduction of metallic and pneumato-

[1] *Mem. Geol. Surv. India*, XXXVII, p. 299.
[2] *Rec. Geol. Surv. India*, XXXVI, pt. 3. p. 169.
[3] C. R. de la XIIE Session, Canada, p. 273.
[4] *Economic Geology.*, VIII, p. 19-50.

lytic constituents; according to the other, their presence in the metamorphosed rock is due to the direct contribution from the invading magma not only of the metallic constituents, but also of the material required for the formation of the silicates.

35. Mr. Burton in his progress report for 1912-13 gives a full account of the metamorphic calcareous series as developed in the Seoni district. He regards the crystalline limestones as derived from sedimentary limestones of various degrees of purity, and accepts the formation of mica, pyroxene, amphiboles, and chondrodite, as due to the re-crystallisation of the original impurities in the limestone, with pneumatolytic addition of fluorine; but the felspar in the quartz-pyroxene gneisses he regards as in part of pneumatolytic origin. He thus favours in the main the re-crystallisation hypothesis. During the past season's work (1913-14) Mr. Burton had the opportunity of devoting further attention to these calcareous rocks as developed in the Balaghat district. This led to an interesting development of ideas, so that whilst Mr. Burton still supposes that the calc silicate minerals of the calc-gneisses (calc-granulites) were in part derived from original impurities in the calcareous sediments, he lays stress on the fact that the predominant felspar is microcline with varying amounts of orthoclase, plagioclase being present only in small amount or altogether absent. He deduces that this microcline was derived from the associated ortho-gneisses during folding, when the latter became re-fused and attained the condition of an igneous magma containing gases and pneumatolytic agents. The felspars both of the calc-gneiss and of the ortho-gneiss show quartz inclusions (*quartz de corrosion*), and this, Mr. Burton thinks, indicates that the calc-gneiss and the ortho-gneiss must have crystallised under the same conditions of pressure, indicating that the calc-gneisses are really mixed gneisses which have re-crystallised under plutonic conditions.[1]

The origin of the kodurite series, Vizagapatam.

36. In his account of the manganese-ore deposits of India[2] Dr. Fermor gives a list of the rocks intrusive into the rocks of the gondite series. These intrusive rocks are all varieties of granite, pegma-

[1]During the present field season (1914-15) Dr. Fermor has accepted Mr. Burton's idea that these rocks are mixed gneisses, and both he (in Chhindwara) and Mr. Burton (in Balaghat) have arrived at the conclusion that the hybridism has, at least in part, been effected by the *lit-par-lit* intrusion of the calcareous rocks by an acid magma. In Chhindwara however, labradorite is as abundant as microcline in the calc-gneisses.

[2] *Mem. Geol. Surv. India*, XXXVII, p. 336.

tite, or felspar-rock, and many of them carry in addition one or more manganese-bearing minerals, amongst which may be enumerated spessartite-garnet, blanfordite, juddite, brown manganese-pyroxene, a yellow manganese-amphibole, braunite, and greenovite, the manganesian variety of sphene. Since these acid intrusive rocks carry manganese-bearing minerals only where they pierce manganese-ore or associated gonditic rocks, it cannot be doubted that the manganese has been taken into solution from the invaded rock and incorporated in the intrusive whilst it was still in the molten condition. These manganesian acid rocks must, therefore, be regarded as hybrids. The highly manganesian composition of the kodurite series of Vizagapatam, described by Dr. Fermor as igneous intrusive masses, which, by differentiation have resolved themselves into whole series of rocks ranging from ultra-basic to ultra-acid, has always been a matter of surprise. For it has been difficult to understand how the ordinary processes of segregation within the Earth's crust could have led to the development of a magma so high in manganese as the kodurite series, which stands alone as a unique series amongst the rocks of the world as at present known. We have indeed, the remarkable case in India of two series of rocks, each rich in manganese, each characterised by an abundance of manganese-garnets, and yet one of them, the gondite series, undoubtedly a metamorphosed sedimentary series, and the other, the kodurite series, an intrusive igneous series. The relationship of these two series one to the other is unfortunately not at present known owing to our ignorance of the geology of certain tracts of country intervening between the regions where the two series are respectively developed. Dr. Fermor now suggests that the kodurite series may perchance be an example of hybridism on a large scale, in which, instead of a small pegmatitic or granitic intrusive having taken up a small portion of an ore-body, as in the manganesian pegmatites intruded into the manganese deposits of the Central Provinces, a granitic intrusive of some magnitude has bodily assimilated entire manganese-ore deposits. It does not follow that the constituents of the dissolved manganese-ore bodies became uniformly distributed throughout the magma; each patch of koduritic rock as we now see it enshrouded in apatitic quartz-felspar-rock may represent the approximate locus of one fragment of the incorporated ore deposit, and the gradation from the ultra-basic garnet-rock in the centre, through basic kodurite, to acid kodurite at the periphery would then represent the results of the gradual diffusion of the dissolved body of manganese-ore into the granitic magma. The apatite so characteristic of the kodurite series would probably have been supplied by the invading magma. This idea can of course, at present be regarded only as an interesting speculation needing for its confirmation the discovery in the kodurite country of older sedimentary manganese-ore deposits or manganese-silicate-rocks. Such rocks have not yet been satisfactorily identified, but certain manganese-pyroxenites, which are closely associated with presumed metamorphosed sediments (khondalites and calc-gneisses) at Taduru and Chintelavalsa,[1] and which Dr. Fermor was not able satisfactorily to connect with the kodurite series, may represent such sedimentary manganiferous layers modified perhaps by contact metamorphism.

37. Unfortunately very little analytical work has yet been carried out on the garnets of these two manganiferous series ; but such material as is available indicates that the garnets characterising the gondite series must be regarded as varieties of spessartite with a low percentage of lime ; whilst those characteristic of the kodurite series, for which the name spandite has been suggested, carry a relatively high percentage of lime. If there be any truth in the idea that the kodurite masses are to be regarded as a product of hybridism, then the high lime contents of the spandite will probably be due not to the solvent magma having been rich in lime, but to calcareous rocks having been picked up along with the manganese-ore body. Such rocks are seen in actual contact with the manganese-pyroxenites of Taduru and Chintelavalsa, and xenoliths of crystalline limestones are actually enclosed by the koduritic masses of the Kodur mine.

38. Associated with some of the gonditic ore bands of the Central Provinces we frequently find (especially where the country of the ore body is ortho-gneiss instead of the more customary mica-schist or quartzite) a small amount of spessartite-bearing gneiss or of orthoclase or apatite-gondite. Such rocks are probably to be regarded as hybrids between the manganiferous sediments and the enclosing ortho-gneiss, and it is to be noted that apatite-orthoclase-gondite is closely comparable with quartz-kodurite, each rock carrying quartz, orthoclase, and apatite, but with different varieties of manganese-garnets. No analysis has yet been made of the manga-

[1] *Mem. Geol. Surv. India,* XXXVII, pp. 21, 22.

nese-garnets in the pegmatitic intrusives into the gondite series, but in habit and colour they are indistinguishable from the manganese-garnets in the gonditic rocks and thus are probably spessartite. In his progress report for 1913-14 Mr. Burton attaches the name quartz-kodurite-pegmatite to a rock from the Netra mine, Balaghat district, but this term will only be strictly applicable if the garnet be high in lime.

39. If future investigation should support this idea that the kodurite rocks are really hybrids, it will introduce a pleasing homogenity into the whole question. It will also suggest the possibility of correlating a portion of the manganiferous rocks and associated sediments of the Central Provinces with the manganese-pyroxenites of Taduru and Chintelavalsa and their associated sediments, which are khondalites and calc-gneisses. Mr. Burton has already suggested the correlation of the calc-gneisses of the two regions on the basis of the associated sillimanitic rocks found both in Balaghat in the Central Provinces and in the Vizagapatam district.

Microchemistry.

40. While on study leave in Europe this summer Dr. W. A. K. Christie, besides making a study of the assaying methods in use at the Royal Mint, London, was engaged chiefly in microchemical work during the summer session in the laboratory of Professor F. Emich at the Technische Hochschule of Graz, Austria, and during the autumn in that of Professor N. Schoorl at the University of Utrecht, Holland.

41. At Graz the quantitative methods worked out by F. Emich and J. Donau were studied in detail. The chief difficulties hitherto encountered in India in quantitative microchemical analysis have been the making and repair of the delicate apparatus required, more particularly in connection with the Nernst-Emich microbalances of quartz fibre and the Donau platinum filters. The technique of manufacture and manipulation having been acquired, attention was chiefly directed to such determinations as would be most useful from a mineralogical point of view, and latterly to new methods for the micro-analysis of silicates, a subject on which, up till then no work had been done. The results obtained were distinctly encouraging.

42. In Utrecht a study was made of the microchemical reactions and separations already worked out with systematic completeness by Professor Schoorl, and advantage was taken of the latter's wide experience in applying the methods to the analysis of complicated ores and rock-forming minerals.

43. The application of microchemical methods and particularly of quantitative ones, has hitherto been greatly neglected in geological work not only in India and a knowledge of them cannot fail to be of service in many instances where only minute quantities of material are available for investigation.

PALÆONTOLOGY.

Tertiary Mammalia: Siwalik Primates.

44. Dr. G. E. Pilgrim acted as Palæontologist throughout the year. He was engaged in the revision of the Siwalik *Primates*, including both the specimens on which the species *Dryopithecus punjabicus* Pilg., *Sivapithecus indicus*, Pilg. and *Semnopithecus asnoti* Pilg. were originally founded but with no more than a brief preliminary notice, as well as additional material obtained since 1910.

45. The results of his examination are contained in a paper published in part 1 of the present volume of these *Records*. A maxilla and upper teeth of the species *Dryopithecus punjabicus* have been described, and two new species of *Dryopithecus* established. A new genus, *Palaeosimia*, which Dr. Pilgrim considers ancestral to the Orang, has been described and the species *Semnopithecus asnoti* has provisionally been assigned to the African genus *Cercopithecus*. Several additional lower teeth and portions of the mandible of *Sivapithecus* have been discovered, which, in the author's opinion display a decidedly human affinity. These, occurring as they do in a Miocene species, point to their owner being an early member of the *Hominidae*.

***Indarctos* and *Dissopsalis*.**

46. Dr. Pilgrim has also written papers, published in the last volume of these *Records*, descriptive of a new genus of bear, *Indarctos* from the Middle Siwaliks, and of a new creodont genus, *Dissopsalis*, from the Lower Siwaliks. The latter represents a curious survival in India of a type, which had become extinct elsewhere, its nearest relatives being found in Eocene genera of Europe and North America.

***Sivaelurus* and *Paramachaerodus*.**

47. The present part contains a paper by Dr. Pilgrim on two new genera of cats from the Lower and Middle Siwaliks, *Sivaelurus* and *Paramachaerodus*. These are allied to species from Pikermi and Maragha and seem to afford evidence of a special line of development not hitherto rechgnized.

48. Mr. G. de P. Cotter towards the end of the year announced the discovery in Burma of mammalian remains in beds which he believes to correspond to the Pondaung Sandstone and to be of Upper Eocene age. If this proves correct these are the earliest reported land mammalia in Asia.

Middle Eocene Mammalia of Burma.

49. Mr. Hallowes was deputed during last July to examine a bone deposit which was reported to occur in the neighbourhood of Kalka. Mr. Hallowes located it near Baddi, some 15 miles north-west of Kalka. The locality is known to Dr. Pilgrim, who assigns the beds to the Pinjor zone of the Upper Siwaliks. Mr. Hallowes brought back a collection of mammalian remains, of which the most interesting are some teeth and vertebræ of *Sivatherium* and a tooth of *Equus*. The latter genus has not previously been recorded from this horizon, and Dr. Pilgrim suggests that its occurrence here may make it necessary to shift these beds to a somewhat later position in the geological scale than had hitherto been suspected.

Upper Siwalik bone bed near Kalka.

50. Mr. E. W. Vredenburg is still engaged on his description of the Oligocene and Miocene mollusca of North-West India, which, however, is now approaching completion.

Tertiary Mollusca of North-West India.

51. Amongst the fossils of the Spiti Shales, which were in the late Professor Uhlig's hands, were a few ammonites left undescribed by that author as well as the whole of the *Brachiopoda*. A memoir on these has now been published by Miss Paula Steiger of Vienna as fascicle 5 of the Fauna of the Spiti Shales, *Pal. Indica*, series XV, Vol. IV. With the collection of the Geological Survey of India she has included in her examination certain specimens collected by the Brothers Schlagintweit and now in the Palæontological Museum of Munich. The ammonites belong to the genus *Perisphinctes*. Amongst them are 11 new species, of which 6 are referred to the subgenus *Aulacosphinctes* and 2 to the subgenus *Virgatosphinctes*. Some of these are, however, rather fragmentary. The *Brachiopoda* are poorly preserved, and Miss Steiger has referred them to the groups of *Rhynchonella lacunosa* Quenst., *Rhynchonella trilobata* Zeiten. and *Rhynchonella Asteriana* D'Orb., merely suggesting their respective affinities, but without venturing actually to identify them with pre-

Palæontological work in Europe : Spiti Shales fossils.

viously known species. The results of her examination are in entire agreement with those obtained by Uhlig.

Ordovician and Silurian of Northern Shan States.

52. Mr. F. R. Cowper Reed has completed a supplementary memoir on new Ordovician and Silurian fossils collected in the Northern Shan States by Messrs. T. D. LaTouche, J. Coggin Brown and others in the year 1904—07. This will be published very shortly.

53. The species described not only augment the lists published in the author's previous memoir of 1906 to the extent of rather more than 100 species, including one new lamellibranch genus, *Shanina*, and 39 species which are new to science, but also provide evidence of a more complete stratigraphical sequence than was at first recognised. A more satisfactory correlation has been rendered possible by the discovery of well-known European zone graptolites, and of other fossils showing affinities to species of known geological horizons.

54. As Mr. LaTouche had the advantage of Mr. Cowper Reed's provisional determinations, the majority of the latter's stratigraphical results have been embodied in his memoir on the Geology of the Northern Shan States published in *Mem. Geol. Surv. Ind.*, Vol. XXXIX, pt. 2 (1913).

55. The faunal affinities of the Upper as well as of the Lower Naungkangyi beds are clearly shown to lie with the Ordovician of northern Europe and not with that of America. The whole facies of this fauna is different, both from that of the Central Himalaya, of Tonkin and of Sze-chuan in China, but shows certain resemblances to that collected by Mr. Coggin Brown in Western Yünnan. Mr. Cowper Reed refers the Naungkangyis, both in their upper as well as in their lower portions, to the lower Ordovician. The fossils of the Hwe Maung or Upper Naungkangyi beds of the eastern area indicate a slightly different age to those of the western area, but the palæontological evidence is insufficient to decide which of the two is the older. The Panghsa pye beds are shown to be of Lower Llandovery age, and have equally a European stamp in which they agree with beds of a similar age from the Central Himalayas.

Ordovician and Silurian of West Yünnan.

56. Mr. Cowper Reed has also completed his description of the fossils collected by Mr. J. Coggin Brown from the Ordovician and Silurian beds of Western Yünnan. This will be published within the next few months. The results of Mr. Cowper Reed's provisional determinations have already been made known in these *Records* in a short paper by Mr. J. Coggin

Brown, *Records Geol. Surv. India*, XLIII, p. 327. Some 70 species are described in addition to 25 species of graptolites identified by Miss Elles with previously known forms. Of these, 20 are new to science, including two new cystidean genera, *Sinocystis* and *Ovocystis*. The Ordovician fauna may be assigned to the lower portion of that system, though probably occurring at four or five slightly different horizons. Like that of the Northern Shan States, its affinities are with the North European rather than with the American type, and present an altogether different facies from the Ordovician fauna of Eastern Yünnan and Tonkin described by MM. Mansuy and Deprat. His failure for the most part to recognize any species, which are actually identical with those of the Naungkangyi beds, inclines Mr. Cowper Reed to place them, however, on a slightly different horizon. The fauna which most resembles that of the Northern Shan States is that found at Shihtien, which recalls that of Sedaw.

57. The Silurian is represented only by the graptolites from Shihtien, which Miss Elles regards as of Llandovery age, though of two horizons not far apart from one another, of which the higher belongs to the base of the zone of *Monograptus sedgewicki*.

Namyau Brachiopoda of Northern Shan States.

58. A large memoir on the Namyau Brachiopoda of the Northern Shan States by Mr. S. S. Buckman is drawing near to completion. A preliminary notice of this memoir and a brief summary of its contents were published in part 1 of the present volume of these *Records*. Its most striking feature seems to be a proposed new classification of the genera *Rhynchonella* and *Terebratula*, based on the internal characters as displayed by burning off the test. The original genus *Rhynchonella* is sub-divided into 44 genera, and *Terebratula* into 32. The Burmese species of *Rhynchonella* are about 40 in number and have for the most part been referred to the new genus *Burmirhynchia*, while the Terebratulids amount to some 20 species belonging to the genus *Holcothyris*. Mr. Buckman considers that the beds are of Bathian age about the date of the great Oolite.

Fauna of the Gieumal sandstone, etc., of Spiti.

59. Dr. A. Spitz's description of the fossils from the Gieumal Sandstone has been translated by Mr. Vredenburg and published in Vol. XLIV, part 3 of the *Records*. The specimens described were originally collected by Stoliczka, Griesbach, Krafft, and Hayden. They include principally bivalves (mostly *Cardium* and *Pseudomonotis*), mostly peculiar to this formation, and a few incomplete ammo-

nites (*Astieria, Parahoplites*, and *Stoliczkaia*). The fauna is too localised to allow a very definite determination of the age of the beds which may range from Upper Neocomian to Gault.

60. Dr. Spitz has also described and figured the foraminifera from the overlying Chikkim Limestone of Spiti, including *Nodosaria, Cristellaria*, and *Textularia*, none of which, however, are of definite stratigraphical value.

61. The paper finally contains a description of some fossils from Griesbach's so-called Chikkim Limestone of Hundes (Mem. XXIII, p. 80) including *Cucullæa, Astarte*, and a belemnite related to *B. Gerardi*, which are evidently not of Upper Cretaceous age (the probable age of the genuine Chikkim limestone), and may indicate the presence of an *exotic block* of Upper Jurassic or Lower Neocomian age.

Upper Ranikot lamellibranchs of Western Sind.

62. Messrs. Cossmann and Pissarro's description of the lamellibranchs from the Upper Ranikot of Western Sind, is being translated by Mr. E. W. Vredenburg. When ready, it will be published in the *Palæontologia Indica*, and will complete the molluscan fauna of the Lower Eocene of Sind of which the *Gastropoda* were published in Vol. III, part 1 of the *Palæontologia Indica* (New Series).

63. As might be expected from the generally wider geographical distribution of bivalve molluscs as compared with gastropods, the Ranikot lamellibranchs do not represent quite so isolated a fauna as the previously described gastropods. In addition to certain forms either previously described by d'Archiac and Haime, or newly established by Messrs. Cossmann and Pissarro, that are peculiar to Sind, several species previously known from the Eocene of Egypt or Europe have also been recognised, such as *Ostrea multicostata* Desh., and *O. Pharaonum* Oppenheim.

Echinoids of the Bagh beds.

64. A revision of Dr. P. M. Duncan's types of the echinoids of the Bagh beds by M. Fourtau has been received and at present is in process of translation from the original French by Mr. G. H. Tipper.

Cretaceous and Eocene of Central Tibet.

65. A description of Dr. H. H. Hayden's collection of Cretaceous and Eocene fossils from Central Tibet by M. Henri Douvillé has also been received. As the translation of this, also by Mr. Tipper, is still in progress, the review of the contents is postponed till the next General Report.

ECONOMIC ENQUIRIES.

Bauxite.

Central India and Central Provinces.

66. In 1913, at the conclusion of his work in Korea State, Dr. Fermor visited Amarkantak (3,500 feet), forming the culminating eastern peak of the main Satpura range, in order to ascertain whether this great height was due to a greater thickness of the Deccan Trap than usual or to the existence of a pre-Trap peak of crystalline rocks. On the way up the Ghat he found that the surface of the gneiss rose to a height increasing from 2,570 to 2,660 feet, the lower portion being overlapped by a hundred feet of Talchir-like rocks. Resting on the Talchirs, "Lameta" limestone was found through an elevation of 90 feet, this excessive thickness indicating perhaps a continued rise of the underlying gneissic surface. This limestone was succeeded by about 670 feet of Deccan Trap lavas, capped by laterite. This was seen through a difference of elevation of 140 feet; but as the laterite was obviously covering a rising surface of trap its actual thickness was much less than this figure, probably not more than 65—70 feet. Amongst the detritus obscuring the exposures on the Ghat road was a great abundance of fallen laterite blocks, many of which consisted of bauxite, often pisolitic and apparently of the best quality. On the plateau of Amarkantak a considerable quantity of bauxite of variable quality was noticed, and even the numerous temples congregated round the source of the sacred Narbada river were mostly constructed of this material. There is a considerable area of ground covered by laterite in this neighbourhood, both in Rewah State and in the Mandla and Bilaspur districts, Central Provinces; and should a careful examination of these hills lead to the discovery of bauxite deposits of any size they might prove to be of ecomomic value; for although the locality is somewhat remote, yet a good site for water power is close at hand.

67. In 1912 Sub-Assistant M. Vinayak Rao discovered bauxite of good quality, on the Amagarh scarp seven miles south-east of Seoni town in the Seoni district; this he further investigated the following year. No excavations have been made, but blocks of bauxite were traced for about two miles and a representative block examined

in the Geological Survey laboratory gave the following results on analysis :—

SiO_2	1·36
TiO_2	12·08
Al_2O_3	54·78
Fe_2O_3	3·17
H_2O	28·25
	99·64

68. In 1913 Mr. R. C. Burton, working to the south of Amagarh, discovered blocks of bauxite in ferruginous laterite at many localities, *e.g.*, Senduria, Amutpani, Patrai, and west of Salai. Near Atarwani, still further to the south in the same district, Mr. Burton found a small hill containing a deposit of bauxite estimated to be twenty feet thick, and lying between beds of ferruginous laterite. Blocks of 70—80 cubic feet in volume lie on the hill sides, but the area covered by the outcrop is small. The quality was apparently good.

Coal.

Wetwin: Northern Shan States.

69. At the instance of the Government of Burma, Mr. J. Coggin Brown during December examined the coaly material of Wetwin, 9 miles (as the crow flies) east of the Lashio branch of the Burma Railways at Wetwin station.

70. Mr. Brown was unable to determine whether the coal seams were comparable with those carbonaceous shales which are interbedded with the limestones belonging to the Plateau limestone (Devonian) of LaTouche (see Geology of the Northern Shan States, *Mem. Geol. Surv. of India*, Vol. XXXIX, pt. 2, p. 255) or to the Tertiary strata of the Shan States and Upper Burma, to which latter it has a remarkable resemblance. The high dip of the strata is, however, against the latter interpretation, if the Shan States only be considered, although in Southern Yünnan, according to the Indo-China geologists, exactly similar deposits often exhibit a steep dip.

71. Three outcrops are described, all lying, as Mr. Brown thinks, at about the same horizon. The coal is a dull black colour, resembling carbonaceous shale. On exposure to the air it quickly crumbles to powder. Three carefully sampled lots of the material have been

assayed in the laboratory of the Geological Survey with the following results :—

Sample number.	Moisture.	Volatile Matter.	Fixed Carbon.	Ash.	Colour of Ash.	REMARKS.
1	17·44	37·84	33·56	11·6	Brown.	Does not cake.
2	16·94	39·19	34·43	9·44	Do.	Do.
3	14·80	38·10	32·78	14·32	Buff.	Do.

In considering these analyses it is necessary to remember that they were all performed on exposed and weathered material, but, taken as a whole, they all show a high percentage of moisture and ash, and that preponderance of volatile matter over fixed carbon which is usually associated with the lignites or brown coals of Tertiary age.

72. No estimates have been made of the total quantity of the coal available, as this could not have been done without extensive operations and possibly borings. Apparently the coal has not been successful as a boiler fuel, and all the objections brought forward by LaTouche and Simpson to the Shan States coal (*Rec. Geol. Surv. of India*, Vol. XXXIII, pt. 2, pp. 117, 125) apply with equal force to this Wetwin material, and in addition there is the long lead to the railway over bad country. For these reasons, and because briquetting would be necessary, Mr. Brown thinks that the coal possesses very little economic interest at the present time.

Western India : proposed borings.

73. The speculative question of the existence of incropping coal measures in Western India beneath the covering of Deccan Trap (on the analogy of those beneath more recent formations in Kent and Northern France) dates back to enquiries put before this department in 1907. The matter came definitely to a head in June of the year under report by the forwarding to this department, by the Agent to the Great Indian Peninsula Railway, of certain correspondence with the Board, wherein Mr. F. L. G. Simpson, Manager of the Mohpani Colliery, put forward the specific localities of Kalyan, Bhusaval and Khandwa, as those at which he considered the overlying Deccan Trap might be thinner than elsewhere, and so be suitable for experimental borings in the hope of reaching coal at no greater depth than 250 feet.

74. The subject, in spite of its discouragingly problematical character, was referred to Mr. C. S. Fox, who was more familiar with the geological conditions of this area than any one else in India at the time. His investigation of the geological literature of the subject indicated :—(1) that the deposition of the Gondwana coal-bearing rocks began in a series of isolated depressions, roughly arranged in definite lines; (2) that a partly water-worn mountain chain stretched in an easterly direction across the Peninsula, corresponding with the present position of the Satpura range and its eastern extension; and (3) that this mountain chain had been breached in at least three places from north to south. The Narbada-Son-Himalaya group of basins lay to the north of the old mountain chain, the basins of the Damodar, the Mahanadi and the Wardha-Godavari rivers crossed eastwards and south-eastwards through the breaks in the chain. The coal-fields were formed at the time when the basins had probably become connected by large sluggish rivers winding their way outwards, west, east and south-east, from the high ground of the uplands over modern Mandla. Not till very latest Gondwana times, however, had the streams a continuous flow, connecting the central regions with the sea. The old basins were probably fault rifts, and at a later date when the volcanic eruptions of the Deccan Trap arrived, further movements along the fault planes appear to have taken place, in some cases preserving whole coal-fields within the limits of their original deposition.

75. The possibility of the existence of coal under the trap of the Bombay Presidency depends upon the existence of another line of Gondwana basins under the traps. This seems a possibility in view of H. B. Medlicott's opinion that the Satpura basins almost certainly had an outlet to the west.

76. After considering the altitude and situation of various localities proposed for borings, Mr. Fox's conclusions, with which I am in agreement, are summarised in the final paragraph of the note put up by him, in which he writes :—" It will, I think, be a waste of time and money to sanction borings that are to be restricted to a depth of 250 feet. If the intention is to exploit the area in a purely experimental manner, then two borings of 1,000 feet each should be put down, one at Bhusawal or Dhulia and the other at Kalyan. In each case the whole operations must be treated in the spirit of sheer pioneer work. If a timid boring of 250 feet is all that can be considered, I have little hesitation in saying that it is not likely to

get through the traps, and very little information for future guidance will have been obtained; whereas, a boring carried through the trap, even if it does not hit a coal seam at once, will give information that should definitely settle the prospects of finding coal under the trap of Western India."

77. It is to be hoped that this critical opinion of the proposals will not deter, but rather stimulate, the Board to sanction the deeper borings (proper care being taken of the cores brought up) for it cannot be denied that as regards Western India such trials will have to be made sooner or later in the interests of water, coal or both.

Limestone.

Upper Assam.

78. The demand for limestone for certain parts of Upper Assam has long been a pressing one, owing to the scarcity there of such deposits. Numerous enquiries from time to time have been received by this department from the Assam Government, the Railway authorities and private firms regarding suitable stone for agricultural and building purposes, and one more readily accessible than that of the celebrated, but distant, Sylhet quarries.

79. The majority of these enquiries centred round the locality of the Mikir Hills, where Nummulitic limestone of the same formation as the Sylhet stone, has long been known. Finally this department was definitely asked by the Assam Government to depute an officer to make a detailed examination of the deposits of these hills, with the particular object of selecting a locality where a limestone industry would have the greatest prospects of success, and be favourably situated as regards the railway. At the end of October, I was able to depute Sub-Assistant M. Viṇayak Rao for this purpose before taking up his regular cold weather work. Notwithstanding the adverse climatic and other conditions he succeeded in selecting three localities in the Disboi Jan, Meyongdisa and between Borojan and Deopani, where a suitable quality and amount of the limestone could be best obtained.

Manganese.

Central Provinces.

80. In the course of his work in western Balaghat, Central Provinces, Mr. Burton visited several manganese quarries and collected notes about five deposits not described by Dr. Fermor in his memoir on the subject, namely, Gola

Hurki, Netra, Biahtekor, Bukoda, and Chibarghat nala, north-west of Budbuda, of which the last three had been abandoned owing to the poor quality of the ore. The ore bed at Gola Hurki and Netra is 15 ft. and 16 ft. thick respectively and carries a fair quantity of ore of good quality. A pegmatite at Gola Hurki contains well developed crystals of braunite, up to 2 inches in diameter, and often twinned.

Potassium Salts.

81. In July Dr. W. A. K. Christie, in the company of the Chief Inspector of Mines in India and the Assistant Commissioner, Northern India Salt Revenue Department, Khewra, visited the Prussian potash mines at Stassfurt to study the mineralogy of the deposits and the methods of mining employed, with a view to utilising the knowledge gained in connection with the possible development of the potash deposits at Khewra and Nurpur in the Punjab Salt Range, the investigation of which formed the subject of a report already published in the *Records* in the year under review. The Prussian deposits differ markedly from those found in India. They are, of course, incomparably greater in extent, but mineralogically there is also a wide difference; although both were probably similar at the time of their deposition, the Punjab deposits have been affected to a much greater extent by thermal metamorphism, so that carnallite, for instance, one of the chief products mined at Stassfurt, is unknown in India.

82. Since the outbreak of war the subject has assumed an added importance, for the main sources of the world's supply—the deposits in Germany and Austria—have been cut off. Although no real potash famine has supervened, chiefly owing to the reopening of many neglected sources in Europe and America, the possibility of the economical exploitation of the Indian deposits has been enhanced, and the subject is now engaging the attention of the Government of India.

Road Metal.

For Calcutta.

83. In July 1914 the Chairman of the Calcutta Corporation, after some correspondence on the subject, asked for the services of an officer of this department to inspect certain localities within a reasonable distance of Calcutta, with a view to selecting quarries that would yield a suitable stone for road metal for the Calcutta streets. The Corporation required

about 20 lakhs of cubic feet per annum of stone for at least 20 years for this purpose, or in other words 40,000,000 cubic feet altogether; and, for reasons connected with efficient breaking and screening, desired to acquire or lease a quarry in preference to the old method of giving out contracts from year to year for supplying the stone.

84. Dr. Murray Stuart, who had recently returned from deputation to Madras, was opportunely available, and was instructed to comply with this demand. During the latter part of August he inspected 12 localities from which offers of leases had been made, and he eventually selected the hill of Deccan Trap called Malphari near Pakur in the Sonthal Parganahs, as being the most suitable, because it would allow a quarry to be excavated with a face of rock at which to work. Mention was also made in his report of other less desirable localities, where it was probable that a large supply of boulders could be obtained, with the likelihood of solid rock being found a short distance below the surface, though there was no proof of this and water troubles would be sure to occur in the rainy season.

Water.

85. Early in the cold-weather season of 1912-13 enquiries were made of this department by the Sanitary Engineer to the Central Provinces Government regarding the probabilities of obtaining a supply of water from tube wells sunk in Berar and Nimar districts of the Central Provinces, where existing wells were shallow, and rock encountered comparatively near the surface. In particular, our opinion was asked if there was a reasonable chance of success if some trial borings were made with two or three hand-power diamond drills suitable for boring to a depth of about 250 feet. This began a correspondence which, early in the summer of 1914 resulted in my deputing Mr. C. S. Fox, who was geologically surveying the neighbouring districts of the Central Provinces, to visit the area at the close of his field season. Mr. Fox accordingly spent the latter part of April till the middle of May examining the water-supply conditions in what is known as the "Saline Tract" and neighbouring parts of Akola district, Berar. A very full examination was made, and a detailed report sent in early in August. Mr. Fox's results and conclusions tended to shatter the hope that deeper wells in the alluvium would be likely to yield sweet water, or that still deeper wells piercing down into the trap rock would, as a matter of course, yield water under artesian

Berar, Central Provinces.

or semi-artesian conditions. The procedure which he suggested was to utilise and systematise the present fresh water supplies as far as possible, supplementing them if necessary, from other sources drawn from the better watered northern tracts, and distributing the whole throughout the saline tract by pump and pipe.

Bombay.

86. During the year reviewed a fresh impetus has been given to the study of water questions in the Bombay Presidency. This subject, which for many years in the past had been under consideration from time to time, came prominently forward in July 1912, when the Hubli municipality purchased a boring plant and proposed sinking to a depth of 1,000 feet. Since then, in consequence of the activity of the Agricultural and Sanitary departments in the matter of well-boring operations for water in different parts of the Presidency, the Bombay Government in October of 1914 appointed a committee to examine the results already attained, with the object of laying down a policy to be pursued in the future; and they asked this department for the services of Mr. A. M. Heron (who is deputed annually to the Engineering College, Poona, for lecturing on geology) to advise the Committee on any points on which they may require his assistance.

87. As Mr. Heron was then in camp, carrying on his ordinary cold-weather geological duties in Rajputana, he was only able to do so by correspondence. Mr. Heron, after referring to the known capabilities of the alluvium and Tertiary beds of Sind and Gujrat, and also possibly the gently folded strata of the Kaladgi and Bhima beds for retaining artesian water, was unwilling to criticise the boring sites as recommended by the Committee without local knowledge and a careful personal exploration with the aid of large-scale geological maps. He also drew attention to the speculative nature of all deep borings in the Deccan Trap, either above or below the ghâts, and as to the desirability of preserving the cores brought up for examination by this Department.

88. It may very well be that besides fissures in the Deccan Trap, water also finds its way along the separation planes of the different trap flows, owing to the presence of porous intertrappean beds. The partially confirmed success of the Hubli boring is also of considerable interest. Although the yield of water was not stated, the fact that in a 300 feet boring water rose to within a few feet of the surface and recovered rapidly at 20 feet below that surface, seems to show that it may be necessary to revise our notions as regards the

steeply folded Dharwar rocks being too compact and impervious for the free passage of water and for artesian or semi-artesian conditions to exist.

Ranchi.

89. At the request of the Public Works Department of Bihar and Orissa, Mr. C. S. Fox in May proceeded also to Ranchi to report on the water-supply of the new Central Lunatic Asylum at Kanke, 4 miles north of Ranchi. For this investigation he was well-qualified by his previous experience of water questions in that locality during the preceding year, when in a very full report he had made various suggestions for deepening wells, increasing their yield by tunnels and a filter-crib in the bed of the Doranda stream, and for a small storage supply, in order to meet the increased demand of a growing town.

90. In the present enquiry 50,000 gallons daily were required to be assured. His suggestions for a reservoir, tube-wells and filter-cribs in the stream beds, were considered by him sufficient for the purpose. But, whatever the source or sources finally adopted, Mr. Fox recommended that the water should be supplied to the Asylum through small reservoirs to meet any sudden demand, such as from fire, and that aero-motors should be used to work the pumps in the wells.

The general question.

91. It would seem from the above examples that the question of well water is one which is becoming a pressing one in many of the rather dry and well populated areas in India. In view of this, and of the undoubted fact that much obscurity still envelopes the problems of underground springs and water-saturated zones, it may be advisable in a future field programme (as suggested by my predecessor) to detail an officer to exhaustively examine the whole general question during one or more field seasons. This would not only conduce to a more scientific and complete settlement of the immediate question, but, incidentally, by the examination of the cores brought up by drilling, would be fruitful in geological and other data.

Engineering.

Darjeeling Landslips.

92. Early in May Mr. R. C. Burton was deputed to Darjeeling to make a geological survey of the Happy Valley landslip area, in continuation of similar investigations made in previous years by Dr. Hayden and Dr. Fermor. Furnished with a topographical map on the scale of 20 inches to the mile and showing 10 feet contours, which had meanwhile been com-

pleted down to the base of the slips, Mr. Burton was able to bring the geological examination of this area to an entirely satisfactory conclusion. He submitted a copy of the map with details inserted on it showing the structural condition of the rock, whether shattered or firm, the dip of the bedding and foliation planes, and the direction and localities of the folds and faults, cracks and fissures, traversing it. A descriptive account, supplementary to those of Dr. Hayden and Dr. Fermor, and embodying suggestions for protective measures, accompanied the map and was well illustrated by sections and photographs.

93. Whether or not the particular protective suggestions made by the Geological Survey, and which were afterwards discussed at a meeting of the Darjeeling Safety Committee, be finally accepted by the Government of Bengal, there can be no doubt that the completion of this structure map marks a step forward in the investigation of the Happy Valley slips.

GEOLOGICAL SURVEYS.

Bombay, Central India and Rajputana.

Messrs. C. S. Middlemiss, H. C. Jones, A. M. Heron and N. D. Daru.

94. Mr. Middlemiss remained in charge of the party at work in these areas, but did not himself take the field. The remaining members of the party, as noted in the margin, are the same as those of last year.

Mr. H. C. Jones, Ninbahera District, Tonk State.

95. Mr. H. C. Jones continued the survey of the Nimbahera District of Tonk State, which he began in the present writer's company towards the end of the previous season. The area worked lies between lat. 24° 25′ and 24° 45′ and long. 74° 18′ and 74° 51′ and is included in the 1″ to 1 mile Standard Sheets, Nos. 172, 173, 205 and 206 of the Central India and Rajputana Topographical Survey.

96. As noted in the last General Report this area is broken up by large patches of territory belonging to Udaipur State in which work cannot be carried on at present and large tracts of the area are covered with alluvium. These combined with the disturbance caused by the intrusion of granite and basic dykes, makes the interpretation of the geology of the older rocks difficult. The area gone over rapidly by Mr. Jones and myself last season, together with the

surrounding area was mapped by Mr. Jones in detail, and the general results once more confirm those made last season, that there is a continuous sequence of Vindhyan rocks stretching conformably downwards from the Kaimur sandstone, through the Suket shale, slabby limestone, purple shales and grits with the boulder bed near Binota at the base.

97. The geology to the south and west of the area is much more complicated, but there seems to be no doubt that Hacket's views of two older series is correct.—(1) the massive quartzites mapped by him as Delhis and (2) the schists, phyllites, shales, siliceous limestones and thin bands of quartzite, which he has mapped as Aravallis.

98. These massive quartzites, which occur as long ridges striking and often dipping in a similar manner to the Aravalli rocks, in places appear, owing to folding, to be interbedded with them, but in several places where the rocks have been cut across by streams, undoubted unconformities are seen. These quartzites are more of the nature of a hard sandstone than a quartzite and the oldest beds are usually conglomeratic in character.

99. Near the centre of the area the Aravalli rocks are intruded by a mass of granite and also by basic dykes, and in the extreme south-west of the area by granite veins. West of the granite, which runs in a roughly north and south direction through Pind, these Aravalli rocks are fairly well defined. They strike in a north-north-west direction but near the granite they are penetrated and disturbed by it, and are therefore somewhat confused. Working from it in a westerly direction there is a fairly well marked sequence from red-purple shale passing up into dark grey shales and phyllites, above which come chloritic schists. Then comes a band of gneiss, which is followed to the west by typical Aravalli schists,—at first dark mica schists, with occasional thin bands of hornblende, quartz and chlorite schists. Towards the west, the mica schist becomes full of small garnets, and still further to the west it contains excellent crystals of staurolite and chiastolite with some kyanite. Both the schists and the gneiss contain granite and quartz veins. Between the shales and the phyllites noted above there is sometimes a band of fawn-coloured siliceous limestone. This varies considerably both in character and thickness and in parts seems to be entirely absent. It is largely covered and is much disturbed and cut up by the granite.

100. The gneiss, which appears to be a paragneiss, is very much crushed and altered. It is penetrated by numerous granite veins, which have also suffered from crushing, and which are probably of the same age as the granite near Pind.

101. The relationship of the rocks which outcrop between the granite and the Vindhyan boundary to the east is still doubtful and will probably remain so until the adjoining area of Udaipur State can be taken in hand.

102. The granite seldom makes any surface feature and is almost always covered with soil and alluvium. It is occasionally seen in river beds, and at the foot of the quartzite hills, where it has been protected by the harder rock. It is sometimes seen as small veins and veinlets running in all directions through the Aravalli rocks, but, with the exception of being broken up, no metamorphic action seems to have taken place. The rock is usually of a pink colour, containing very little ferro-magnesian minerals, and practically none of the accessory minerals commonly found in granites. A peculiar pinite granite occurs in parts and is similar to a rock found by the writer in Idar State.

103. Running roughly through the centre of the area in a north and south direction is a large basic dyke, which in parts seems to have spread out as a sill or flow. The rock is a coarse crystalline dolerite, but near the edges it becomes very fine grained and almost glassy in appearance. The dyke is of later age than the Aravallis and the granite, but its relation to the massive quartzites was not seen. Very little metamorphic action seems to have taken place between the dolerite and the Aravalli rocks, but near its junction with the limestone, south of Pind, it is associated with a vein of yellow green epidote, quartz and reddish idocrase. Where this large basic dyke is seen in contact with the granite a peculiar hybrid rock sometimes occurs,—there appears to have been a partial refusion of the granite, resulting in an intermixture of the granite and dolerite. The resulting rock, which has characters between the two, often shows remains of the ophitic structure of the dolerite, whilst there is also a micro-graphic intergrowth of the quartz and felspar.

104. Copper pyrites in small quantity was noted at several places in the schists, and a little galena was found in a thin band of Aravalli chert near Chikara, but with the exception of the flaggy limestone noted last season nothing of special economic importance was found.

105. Mr. Heron spent the early portion of last cold weather in examining sundry mineral occurrences which have already been noticed in last year's General Report. His survey proper in the States noted in the margin was included within the 1″-1 mile Standard Sheets of the Central India and Rajputana Survey, Nos. 291 to 294, 318 to 321 and 341 to 343. Of these Nos. 291, 292, 293, 318, 319 and 341 have now been completely geologically surveyed.

Mr. A. M. Heron: Jaipur, Karauli, Kotah and Tonk.

106. Mr. Heron found the rock series to be composed of (*a*) Aravallis and (*b*) dark foliated granite or gneiss of unknown age. The Aravallis (*a*) build isolated hills and consist of quartzite and mica schist, obscurely stratified, dipping irregularly and very highly altered. They contain numerous masses of intrusive granite identical with that already mapped by Mr. Heron as intrusive in the Delhis in Alwar and north Jaipur. It is very distinctly foliated in a direction coincident with that of the folding. There are also more recent veins of coarse tourmaline pegmatite, cutting through the granite, and which is never foliated. The hill at Koharsina (lat. 260° 54′, long. 75° 4′) exposes much schistose conglomerate unconformably overlying the Aravallis and which Mr. Heron thinks may be of Delhi age, though he was unable to settle this.

107. The dark foliated granite (*b*) found in the neighbourhood of Sakun (lat. 26° 42′ long. 75° 8′) is the same as that described by Mr. Heron in 1911-12, being very dark, micaceous, strongly foliated and visibly porphyritic or augen-bearing, the foliation planes being almost horizontal. It is traversed by pegmatite veins, quartz veins and by trap sills, the latter parallel with the foliation. A hint of its relative age is given by a small exposure just south of Asilpur Station (lat. 26° 54′, long. 75° 28′) where a very black micaceous augen gneiss, resembling the above, is intrusive in quartzite. The augen phenocrysts of pink felspar are so evenly arranged in straight lines with the foliation that the rock can be spilt into flags. Veins of normal pegmatite traverse it and also the quartzite.

108. Mr. Heron has included the work outlined above in a paper, which has been submitted for the *Records*, entitled "The Geology of Dholpur, Karauli and Southern Jaipur."

109. Mr. Daru completed the survey of Sunth State, Rewa Kantha Agency, part of which he had already surveyed in 1912-13. Mr. Daru describes the whole State as practically occupied by schist-like

Mr. N. D. Daru: Sunth, Banswara and Dungarpur.

phyllites underlying massive quartzite, which in turn is overlain by phyllites. These three are said to be conformable. The lower or schistose phyllites often contain large proportions of quartz and hornblende, and, while the upper phyllites also at times have similar bands, they are generally argillaceous and include a few bands of quartzite. They are disposed in highly dipping anticlinal ridges. In the north-east parts of Sunth, and extending into Banswara State, there is a very soft, coarse sandstone, coarsely conglomeratic at the base, uncomformably overlying the phyllites, and having almost certainly the structure of a synclinal trough. Its age is uncertain, but as none of the pebbles appear to be derived from the neighbouring Bagh beds or Deccan Trap, but consist of quartzite and its associates, the soft coarse sandstone may be older than the latter.

On the south-east and east boundary of the State the Bagh calcareous conglomerate, 20 to 50 feet thick, forms a horizontal elevated platform on which appear hillocks and ridges of Deccan Trap. No minerals of economic importance have been met with.

110. Towards the end of the cold-weather season, in March and April of 1914, Mr. Daru revised certain portions of Banswara and Dungarpur States. The results he proposes to embody in a connected report on the whole, which he is now preparing.

Burma.

111. The Burma party consisted of Messrs. G. H. Tipper, G. de P. Cotter, H. S. Bion, and M. R. Ry. Sethu Rama Rau, Sub-Assistant.

Mr. G. H. Tipper.

112. Mr. Tipper, who was placed in charge of the party, visited Yenangyaung, the Minbu-Ngape section, the Yaw river (in company with the Director and Mr. Cotter), Ngahlaingdwin, and the Sinbaungwe township.

Mr. G. de P. Cotter.

113. Mr. Cotter continued the systematic survey of the Pauk township and the Saw township, Pakokku district. Part of the field season was devoted to an investigation of certain coal seams discovered by him in this neighbourhood; the results of this have been published in the *Records*, Vol. XLIV, part 3. At the end of the season he made a traverse in the Pakokku hill-tracts as far as Kanpetlet (sheets 84 K. 3, 4, 6, 7, 10 Burma Survey).

Mr. H. S. Bion.

114. Mr. H. S. Bion worked in the Saw and Salin subdivisions of the Minbu and Pakokku districts (sheets 84 L 1, 5, 6, K 4, 8, Burma Survey).

115. The area investigated by these two officers forms a long strip of undulating country comprising the foot-hills of the Arrakan Yomah between latitudes 20′ 30″ and 21′ 45″ and running north and south parallel to, and east of, the main range.

Area investigated.

116. In this tract the structure is in general a normal sequence of Tertiary beds dipping towards the east below the Irrawaddi sandstones and faulted against the older rocks of unknown age composing the main range of the Arrakan Yomah. This sequence is broken by asymmetric anticlines with their corresponding synclines near Ngahlaingdwin (94°22″40″; 20° 41″ 15″) and at the Yaw river (94° 21″; 21° 17′). The asymmetry is on the western flank and associated with it is reversed faulting. In the case of the Ngahlaingdwin anticline the reversed fault, after running north for some distance as a strike fault, curves round and probably dies out as a dip fault near Saw.

Structure.

117. The principal results of the joint work of Messrs. Cotter and Bion may be thus briefly indicated :—

Main geological results.

(1) The recognition that the Tertiary series of strata underlying the Irrawaddi sandstones is more extensive than was formerly thought to be the case. At present no definite estimate can be given of the thickness, but it is probably approximately 24,000 feet. The series consists of alternations of sandstones, shales and clays, the basal member being composed of conglomerates and ashy sandstones. It shows no unconformable break. The lithological resemblance between the different shale and clay bands is very striking. Local names have been adopted temporarily for many of the divisions and further work will show how far these are capable of wider adaptation.

(2) Traced from south to north, there is a gradual change from marine to fluviatile and estuarine conditions. Clay bands which are prominent in the neighbourhood of Ngahlaingdwin have become sands in the region of the Yaw river and are indistinguishable from the overlying sandstones. As a consequence of this lithological change, the faunal and lithological subdivisions are not in agreement from south to north. It is quite clear that the gulf, in which it may be assumed this series

of beds was laid down, silted up at an earlier period in the north, the shallow water beds of the north thus being contemporaneous with deeper water deposits further to the south.

(3) The "Red Bed," usually taken as the boundary between the Irrawaddi sandstone and the underlying formation, and which has proved of such value in unravelling the stratigraphy of the oilfields, is not of the same age throughout. The "Red Bed" no doubt represents an old land surface and as such indicates an interruption of sedimentation, but such conditions were established at an earlier date in the north than in the south.

(4) It is not possible at present to say definitely the limits of age represented by this series of beds. Fossils occur at many horizons, but the collections have not yet been completely studied. A few fossils collected by Mr. Cotter on his traverse to Kanpetlet seem to indicate an upper Cretaceous age for the lowest beds.

Irrawaddi sandstone.

118. In the course of his survey, Mr. Cotter found a very good bone bed near the village of Chaingzauk (sheet 84 K. 10). The remains, chiefly teeth, have been identified by Dr. G. E. Pilgrim, and include :—

Stegodon clifti (molars).
Sus giganteus.
Hippopotamus sp. cf. *irravaticus* (molars).
Rhinoceros sp. cf. *sivalensis.*
Amphibos sp.

A large antelope allied to *Hippotragus.*

Teeth and horn cores representing a new genus of antelope allied to *Boselaphus.*

Recent river changes.

119. The Irrawaddi river, the Salin chaung and the Yaw river have all in recent times changed their courses as indicated by the distribution of the older river gravels. In the case of the Salin chaung the course has been greatly lengthened by the change.

Sub-Assistant Sethu Rama Rau.

120. Sub-Assistant Sethu Rama Rau was engaged during the earlier part of the field season in mapping the Tertiary beds of the Sinbaungwe and Allanmyo townships of the Thayetmyo district (sheet No. 158 Burma Survey).

121. The major part of this area is occupied by rocks of the Pegu series folded into three approximately parallel anticlines and synclines running in a N. W., S. E. direction. Local folding and crumpling accompanied by faulting are common. On lithological grounds Sub-Assistant Sethu Rama Rau thinks it is possible to make four sub-divisions in this area. It has not been possible to correlate these with any of the sub-divisions established in the north as, although the beds are fossiliferous, the collections made were lost in a village fire. Except on the banks of the Irrawaddi and in some of the stream-beds, exposures are everywhere poor, the rocks being concealed under a thick alluvial covering.

Pegu Series.

122. The Irrawaddi sandstones and the more recent formations present no features of interest.

123. In the latter part of the season, Sub-Assistant Sethu Rama Rau was engaged in assisting Mr. Cotter in opening up coal-seams in the neighbourhood of the Yaw river, Pakokku district and in collecting fossils from the lower Tertiary beds of the same district.

Central Provinces.

124. The Central Provinces party during the year consisted as before of Dr. L. L. Fermor, Messrs. H. Walker, C. S. Fox, R. C. Burton, and Sub-Assistant M. Vinayak Rao, of whom Dr. Fermor and Mr. Walker were absent on leave in Europe during the field season of 1913-14, but returned to the party in November. Mr. K. A. K. Hallowes was then also attached to the party for the ensuing field season, being deputed to the Mandla district.

Dr. L. L. Fermor, Messrs. H. Walker, C. S. Fox, R. C. Burton and M. Vinayak Rao.

125. During parts of November and December Dr. Fermor visited Messrs. Burton and Hallowes in the field, examining with Mr. Burton some of the interesting features in western Balaghat elucidated by the latter during the previous field season, particularly the relationships of Mr. Burton's Sonawani series to the Chilpi Ghat series, and the sedimentary and crush-conglomerates bounding the south-eastern margin of the Chilpi outcrop in this region, as seen at Kaspur Tola and other localities. The undoubted autoclastic character of some of these conglomerates led Dr. Fermor to re-examine the rock underlying the Balaghat manganese-ore deposit,

Dr. Fermor's inspection tour.

which he had previously described as a schistose conglomeratic grit, and to agree that it also must be regarded as an autoclastic rock. These crush conglomerates consist now almost entirely of sericite and quartz, but every stage of the transition from felspathic gneisses can be traced.

126. In his visit to Mr. Hallowes in the Mandla district, a commencement was made in the detailed mapping of an area of Deccan Trap lava flows in the north-western portion of the Mandla district. Seven flows were identified, of which the middle five had an average thickness of 98 feet. A system of faulting with small throws up to about 30 feet was also detected; and, in the Balein Nadi, a nearly circular patch of volcanic agglomerate, 25′×17′, strongly suggestive of a small volcanic plug, was detected in a water-worn exposure of the second flow from the base.

127. The work in the Central Provinces is leading to the discovery of a surprising number of cases of faulting of post-Deccan Trap age. Early in 1913 Mr. Burton discovered a case, near Alesur in the Seoni district, of the preservation by block faulting, with a downthrow of 40—50 feet, of a strip of Deccan Trap resting on gneiss. In the same year Messrs. Fermor and Fox, whilst revising their map of the Deccan Trap lava flows in the Linga area, detected a small fault with a throw of about 50 feet and found indications of other faults, whilst in the past field season Mr. Fox discovered numerous examples of faulting of post-Deccan Trap age, in Northern Chhindwara. Dr. Fermor now reports the discovery near Utekata in the Chhindwara district of a spindle-shaped strip of Deccan Trap, about two miles long and three-quarters of a mile wide in the middle, and resting on biotite-gneiss and calc-gneiss, that has been let down 250 feet by block-faulting. The faulted block is itself much faulted by a system of smaller faults with throws of 15—30 feet. The majority of faults referred to above have strikes lying between E. 30°N. and E. 30°S. This suggests the possibility that to a certain extent the present elevation of the Satpura range above the plains to the north and south may be due to a system of block-faulting of post-Deccan Trap age. Mr. Burton also deduces the existence of block-faulting of comparatively recent age from a study of numerous small hanging valleys on the southern edge of the Satpuras in the Seoni district. A fine example of such a hanging valley is also afforded by the Nakta nala in the Chhindwara district. From a study of the

base of the Deccan Trap on the two sides of the Kanhan valley from Ramakona southwards in the Sausar Tahsil, Chhindwara district, Dr. Fermor deduces that this valley must lie along a fault of approximate N. N. W. strike with a down-throw of about 250 feet to the west.

Mr. C. S. Fox : Chhindwara.

128. Mr. C. S. Fox continued his survey of the Chhindwara district, working as before in the Chhindwara and Jagir Tahsils. In the previous year Mr. Fox had divided the Archæan crystallines into three main zones :—(1) a zone of acid ortho-gneisses lying to the south of the latitude of Lawaghogri; (2) a zone of gneisses and schists of obscure origin lying between the latitudes of Lawaghogri and Chhindwara; and (3) a belt of intrusive porphyritic and fine-grained granites running through Chhindwara town. This season's work has led to the discovery of a fourth large group of rocks, namely a considerable area of metamorphosed sediments of Dharwarian facies, composed of grits, quartzites, phyllites, and flags, and exposed around Bhatoria and along the southern edge of the Chhindwara coal fields. These sediments are intruded not only by the Chhindwara granitic batholith, but their strike is also interrupted by two smaller batholiths of similar nature, named by Mr. Fox the Raini and Kunkal batholiths after peaks rising to 2,986 and 2,905 feet respectively, which are the highest summits yet detected amongst the Archæan exposures of this district. Mr. Fox's mapping shows beautifully the way in which these granitic batholiths have modified the strikes of the ancient sediments. Since with increasing intensity of metamorphism the rocks of Dharwarian facies are seen to pass into the rocks of the second zone referred to above, these latter are now regarded by Mr. Fox as para-gneisses. Great masses of intrusive basic rocks have also been mapped. They are older than the granitic batholiths and intrusive with reference to all the other crystalline rocks. They are now mostly in the form of epidiorites and amphibolites, and were introduced as dykes and sills of dolerite and gabbro, sometimes carrying olivine, remnants of the original pyroxenic rocks being sometimes found. Instead of the characteristic alteration into amphibole, the pyroxene has occasionally been changed to biotite, as near the village of Gorakpur (22°6′—78°37′). The amphibolites, where subjected to intense shearing pressure, have sometimes become garnetiferous. Mr. Fox also describes a case near the village of Mankughati

(22°7′—78°32′) in which a band of amphibolite has been marginally converted into crystalline limestone.

129. Mr. Fox also extended his survey through the Jagir country along the Chhindwara-Narsinghpur road to the northern margin of the district, this route lying for the most part on Deccan Trap; but in the northern corner of the district the Shakar and Hard rivers have cut through the Trap and exposed the underlying Gondwana beds of Jabalpur age. These Gondwanas are pierced by dykes of olivine-dolerite, and a great intrusive sheet of the same rock, which shows the effects of repeated post-Trappean step-faulting. In the high tracts of Deccan Trap lying between these Gondwana outcrops and the latitude of Amarwara to the south, Mr. Fox estimates the existence of 1,200-1,500 feet of lava, with the complete absence of fossiliferous Intertrappeans. South of the latitude of Amarwara and Singori the Deccan Trap never exceeds about 500 feet in thickness, and is built up of seven to eight flows with one to three fossiliferous Intertrappean horizons. Mr. Fox suggests that the upper part of the Jagir traps corresponds with the middle traps of the classification given on page 262 of the Manual of Geology of India (2nd Edition), and that there was either an overlap of the flows from south to north, or that the granite ridge formed by the three batholiths already mentioned sharply separates the two areas. The belt of Gondwana rocks underlying the Jagir traps, and which are exposed as the Chhindwara coal fields along the southern edge of these traps, has, according to Mr. Fox, been preserved by trough faulting; and in considering the possible extension of the Gondwanas to the east Mr. Fox thinks that there is little doubt that the upper Gondwanas are continuous under the trap eastward to Jabalpur. The question of the extension of the Gondwana rocks under the Deccan Trap of Western India is considered on page 114.

Mr. R. C. Burton: Seoni and Balaghat.

130. During the season 1913-14 Mr. R. C. Burton completed the survey of those portions of the Seoni district allotted to him, thus, with Sub-Assistant Vinayak Rao, completing the survey of this district. As in the previous season, the chief formations examined were laterite, Deccan Trap, and Archæan gneisses and metamorphosed sediments, the results being a continuation of those of the previous season. In the northern parts of the district Mr. Burton records eight Intertrappean horizons, which, if really distinct, indicate the presence of nine flows of trap, with a total thickness of

775 feet, and an average thickness for the lower eight flows of 92 feet; but in view of the existence of block faulting in the Satpuras, the above figures may require some modification. Mr. Burton describes some interesting cases of amphibolites passing into hornblende-gneiss, apparently by absorption of quartz from the associated older granite.

131. From the classificatory point of view the geological survey of the Balaghat district will probably prove to be of critical importance in the establishment of the true sequence of Archæan formations of the Central Provinces. West of the Wainganga are the alluvial plains of the Katangi-Waraseoni area of western Balaghat, fringed on the north by the foot-hills of the main Satpura range; whilst to the east of this river lies a hilly plateau tract, forming a southward projecting spur of the main Satpura range and known as the Maikal range. This spur has an average elevation of about 2,000 feet and forms the natural continuation on the strike of the highly metamorphosed Archæan gneisses and sediments constituting the 1,000 feet Nagpur-Balaghat plain; and as it contains the same formations in a less metamorphosed form it will probably afford better material for the deciphering of the stratigraphical succession. During this season Mr. Burton surveyed a considerable portion of the Katangi-Waraseoni plain and the hills to the north, but at the end of this season he crossed the Baihir plateau forming part of the Maikal range and examined at Chilpi Ghat the type locality for the Chilpi Ghat series established by Dr. King in 1885. This section shows a great thickness of phyllites and slates with tufaceous quartzites, separated by coarse felspathic grits from a basement conglomerate 450 feet thick, which rests unconformably on a gneissic complex. There is also a great thickness of intrusive basic rocks. The conglomerate carries rolled pebbles of quartzite, gneiss, jasper, granite, and phyllite; and indicates the previous existence of a still older sedimentary series. The Chilpi Ghat series, as is known from the work of P. N. Bose, extends into Westein Balaghat, where Mr. Burton finds it to be composed of the same rocks as in the type locality, including the tufaceous quartzites, but without the basic intrusive sills and with a relatively insignificant basal conglomerate. In the hills north of the Balaghat plain Mr. Burton finds an important development of ancient metamorphosed sediments composed in descending order of (1) phyllitic schist and quartz-muscovite-schist, (2) felspathic quartzite, (3) quartz-mus-

covite-schist, (4) calc-gneiss and crystalline limestone, the base of the series not being seen. Although the evidence is not yet clear, Mr. Burton thinks that this series of sediments must be situated unconformably below the base of the Chilpi conglomerate. He consequently proposes to call it the *Sonawani series*, after the village of Sonawani situated on one of the largest outcrops of these rocks. If this two-fold sub-division of the Archæan sedimentaries of Balaghat into the Chilpi Ghat series and the Sonawani series can be definitely sustained it will be a great step forward. At present, however, owing to the intense folding and thrusting which the rocks of Western Balaghat have undergone, the existence of this unconformity, although probable, has not been definitely proved. Dr. Fermor regards the Chilpi Ghat series as the local equivalent of portions of the Dharwar system of Southern India. Whether the Sonawani series is to be regarded as a lower sub-division of the Dharwar system or as a district geological system as widely separated from the Chilpi Ghat series as the Grenville series is from the Temiskamings of Canada, will depend upon the value assigned to this unconformity. Another interesting point arises from this suggested separation of the Sonawani series. In his account of the manganese-ore deposits of the Central Provinces Dr. Fermor has distinguished two modes of occurrence of manganese-ores and associated manganese-silicate-rocks. The chief mode is the gondite series of rocks situated near the base of the Chilpi Ghat series; as an important but distinct mode of occurrence he records the existence, in association with crystalline limestones, of manganese-ore deposits with associated spessartite, rhodonite, and piedmontite-bearing rocks. Since Mr. Burton assigns to the calcareous rocks a position near the base of his Sonawani series, we apparently have the interesting case of two distinct series of Archæan sediments, each distinguished by the deposition of manganiferous sediments close to the base. In a table in his progress report, attempting the correlation of the Archæan rocks of India, Mr. Burton suggests the equivalence of the calc-gneisses of Vizagapatam with those of the Central Provinces. This is in accord with the association of manganese-pyroxenites with calc-gneisses at Taduru and Chintelavalsa already referred to (see page 104), and suggests that the material for the formation of the koduritic rocks, if they really be hybrids as suggested by Dr. Fermor, has been derived from manganiferous rocks of age corresponding to the lower manganese horizon of the Central Provinces.

132. The ideas advanced by Mr. Burton concerning the origin of the calc-gneisses and the crystalline limestones of the Sonawani series are referred to on page 102.

133. In addition to the sedimentary conglomerates Mr. Burton has discovered numerous cases of crush-conglomerate and related rocks developed in the Archæan formations of this area. The most peculiar of these takes the form of flattened ellipsoidal and tabloid-like bodies developed in biotite-gneisses and granite and evidently due to crushing. These bodies, which are autoclastic portions of the rock in which they lie, now consist almost entirely of quartz and sillimanite. The conversion of the potash-felspar of the original rock into quartz and sillimanite is supposed by Mr. Burton to have taken place in two stages during dynamic metamorphism, muscovite being first formed under more moderate pressures and becoming converted into sillimanite as the metamorphism became more intense. The biotite apparently may have passed direct into sillimanite. The alteration processes involve the removal of potassium, magnesium, and iron in solution, probably as carbonates, as can be shown by chemical equations.

134. The work in the Central Provinces is confirming the old idea that the Satpura range, as we now know it, is the denuded remnant of an ancient mountain chain and that its elevation is connected with the folding of the rocks constituting it. This idea is supported both by Mr. Fox and Dr. Fermor and the latter has maintained[1] that the intrusion of the granites which formed such a large portion of the Satpuran core was intimately bound up with the tectonic movements to which the Satpuras owe their elevation, suggesting that the intrusion of the granite was the cause of the upheaval. Mr. Burton, from a study of the evidence in Balaghat and Seoni, indicates that the folding movements preceded and permitted the intrusion of the batholithic granitic rocks, and that the intrusion was succeeded by thrusting movements, of which there is abundant evidence in the form of the crush-conglomerates already referred to.

Sub-Assistant M. Vinayak Rao: Seoni and Mandla.

135. Sub-Assistant M. Vinayak Rao continued his work in the Seoni district, mapping parts of sheets 70, 78, 87, 88, 89, and at the close of the season commenced work in sheets 109, 110 in the Mandla

[1] *Mem. Geol. Surv. India,* XLI, p. 165.

district. The formations examined were Archæan gneiss, granite, Deccan Trap, Intertrappeans, laterite, and alluvium, by far the greater portion of the area being covered by Deccan Trap. A great thickness of trap was found towards the western border of the district, where there may be as much as 1,500 feet of lavas. Near Arjunjhir (22°18′—18°0′) six Deccan Trap dykes from one to six feet thick were discovered, ramifying and joining together to form a multiple dyke. Six Intertrappean bands were detected, but they yielded no fossils. In the Mandla district in addition to Deccan Trap, the Narbada alluvium proved to be of considerable importance. It is in places as much as 150 feet thick and near Cheolia (22°50′—80°2′) yielded an implement fashioned from Deccan Trap flint.

Kashmir.

Mr. H. S. Bion.

136. Mr. Bion followed up his work of last year in a north-west direction between the Sind river at Sonamarg and the Wular lake at Bandipur, a region which includes the Haramuk massif and the extensive watershed of ridges separating the Jhelum and Kishenganga drainages (1 inch = 1 mile sheets 43 N-3, 43 J-15 and parts of 43 J-11 and J-16).

137. During the survey of this rough mountainous tract he has filled in a good many gaps in the evidence (previously referred to in the General Report for 1912, *Records, Geological Survey of India*, Vol. XLIII, pt. 1, p. 38) tending to show that within the distance from the Lidar valley to the Wular lake the Punjab Trap has shifted its position from one confined to a pre-Permian horizon to one extending up to the base of the Upper Trias. The evidence may now be considered to be conclusive on this point, as also regarding the manner of that transgression, which all the circumstances of the case favour being one ordinary volcanic effusion (with production of amygdaloidal bands and also pumiceous and ashy beds) and as having taken place at progressive times in different localities, so that the whole set of lavas, dovetailed with the respective sedimentaries, belong to one connected and continuous phase of vulcanicity. As interesting steps in the proofs supplied by Mr. Bion may be mentioned the finding of flows interbedded with the Permian of Nichinai and of a limestone mass containing typical Muschelkalk fossils, such as *Buddhaites Rama*, entirely surrounded vertically and laterally by bedded traps. The same chain of observations makes it probable that the Imbersilwara limestone, about which doubts have

prevailed, is of Lower Triassic age, and is also an isolated lenticle limited in every direction by trap.

138. Over most of the area the Panjal Trap immediately overlies the Slate Series, the Muth Quartzite and Syringothyris Limestone having died out by rapid overlap of the Panjal Trap in the neighbourhood north-west of Gagangiyer, to which place they were originally traced by Mr. Middlemiss.

139. The fossils of the Nagmarg horizon coming below the traps of that place, and originally mentioned (*loc. cit.* p. 38), have been largely worked out by Mr. Bion and will be described in a separate paper. They are considered by him to be of Uralian age, and separated from the Zewan beds only by the Artinskian plant beds of the Guryul ravine, Nagmarg and the Golabgarh pass. The large number of Spirifers found at that horizon, such as *Sp.* nov. sp., and varieties of the Australian *Sp. Stokesii* Koenig, which show closely related and ancestral characters to Zewan forms, is greatly in favour of this.

140. In his detailed progress report Mr. Bion has also described the local modifications of the Permian and Trias horizons, and has added many notes on trap dykes, and on the granite of Wangat and Margund, the latter being considered to be of Devonian age. His observations on the glaciology of the area round Haramuk are of much interest; a great many large and fine moraines have been mapped, some descending to 6,500 feet altitude and perhaps even to 1,000 feet lower than this. Mr. Bion has been led to suspect the former existence of two glacial periods in Kashmir separated by a long interglacial one.

141. Museum Assistant A. Subba Iyer was placed with Mr. Bion for collecting purposes and for instruction in field-work. Mr. Bion found him very willing and anxious to do his best but the nature of the work was perhaps too difficult and complicated for one untrained in the rudiments of field-work.

TRANS-FRONTIER EXPLORATION.

Chitral, Chinese Turkestan and the Pamirs.

Dr. H. H. Hayden.

142. In the course of a recent journey to Europe through Chitral and the Russian Pamirs, Dr. Hayden made collections of rocks and fossils, which reached Calcutta from Kashgar towards the end of the year. From notes

supplied by Dr. Hayden it would appear that the hills of Dir and Swat consist chiefly of basic igneous rocks followed by a series of unfossiliferous, and often metamorphosed, sediments resembling the Purana rocks of the Himalaya. These are separated by a wide belt of granite from a group of agglomerate and trap, evidently the western representatives of the Panjal trap and Agglomeratic Slate of Kashmir. This group of beds is well seen below Drosh in the valley of the Chitral river.

143. In Upper Chitral an interesting stratigraphical series, extending probably from Cambrian to Cretaceous, was found along the Yarkhun river. Interruptions by faults and by intrusive masses chiefly of granite, render the sequence discontinuous, but it was found possible to make fairly extensive collections of fossils; the Upper Devonian beds, from which specimens had already been described by Hudleston in 1902[1] yielded an especially fine collection of brachiopods and corals. At the head of the Yarkhun valley, on the divide between Chitral and the Afghan province of Wakhan, Carboniferous and Permian beds near the Baroghil and Shawitakh passes contain an interesting fauna comprising *Brachiopoda*, *Bryozoa*, *Fusulinæ* (with *Schwagerina*) and *Nautili*.

144. In the Yasin valley, between Gilgit and Chitral, a slaty limestone full of hippurites was found among highly metamorphosed sediments, and Dr. Hayden is inclined to regard the metamorphic rocks of Gilgit, Hunza, Nagar, and N.-W. Kashmir as to a great extent merely the altered representatives of the sedimentary beds of Chitral and as ranging in age from Lower Palæozoic to Cretaceous.

145. Interesting collections were also made in the Pamirs, and Chinese Turkestan, where Dr. Hayden met with the greatest kindness at the hands of the respective Russian and Chinese officials, and particularly at the hands of Sir George Macartney, British Consul-General at Kashgar. In the Russian Pamirs the most persistent and conspicuous stratigraphical element is a very thick limestone series ("Pamir Limestone") containing well-preserved Jurassic ammonites in its upper beds. It was probably from the lower beds of the same Pamir Limestone that Stoliczka collected the Triassic genus *Halorella* near Nezatash in 1874. The limestone is underlain by a great series of shale, sandstone and conglomerate full of intrusions of basic rocks.

[1] *Geological Magazine*, Vol. IX, 3-8, 49-58 (January, February, 1902)

146. In the northern Pamirs, at the eastern foot of the Ak Baital pass, which lies between the Rangkul Pamir and Great Kara Kul (lake) a limestone near the roadside yielded a small fauna of Upper or Middle Devonian age.

147. Dr. Hayden's collections also include *Gryphæa Kaufmanni* (=*Ostrea turkestanensis* Rom.) from the Ferghana stage of the Tertiary of Chinese Turkestan and the Alai, and Fusulina limestone from the latter range.

148. The chief interest of the observations made in Chitral and the Russian Pamirs lies in the fact that, as had been anticipated, they serve to a great extent to explain the differences between the Afghan and Himalayan stratigraphical provinces. The strike of the rocks conforms completely to the general structural conditions indicated by the deep re-entrant bay of alluvium in north-western India; in western Chitral it is approximately S.W.—N.E. gradually bending round, in the mountains surrounding the upper Yarkhun valley, in Yasin and in Gilgit, to W.-E. and finally trending onwards to N.W.—S. E. in the Taghdumbash pamir and Sarikol. It would appear, therefore, that the basin in which the fossiliferous series of Upper Chitral were deposited is the westerly continuation of the geosynclinal of Spiti and Ladakh, and unless obliterated by intrusive igneous material, ought to be found again in the Karakoram range. Indications of its presence there are, indeed, said to have been met with by members of the Filippi expedition during the course of their recent researches.

NOTE ON THE NEW FELINE GENERA *SIVAELURUS* AND *PARAMACHAERODUS* AND ON THE POSSIBLE SURVIVAL OF THE SUBPHYLUM IN MODERN TIMES. BY GUY E. PILGRIM, D.SC., F.G.S., *Officiating Superintendent, Geological Survey of India.* (With Plates 5 and 6.)

In the year 1888 Weithofer[1] founded the species *Machaerodus schlosseri* on two mandibles from the pontian of Pikermi, which possessed a moderately long diastema behind the canine and a characteristic ridge adjoining the symphysis, and in which an abrupt passage took place from the under to the front margin of the ramus, although the descending symphysial flange of *Machaerodus* was absent. He suggested the specific identity of a fragmentary mandibular ramus, described and figured by Kaup [2] under the name of *Felis ogygia*, from Eppelsheim, with the Pikermi species.

In 1885 Kittl [3] described the front portion of a skull from Maragha in Persia under the name of *Machaerodus orientalis*. In this case the size of the upper canine was in defect of that of previously known species of *Machaerodus*, but Kittl considered that the crenulated edge of the canine and certain other characters entitled it to a position in *Machaerodus* rather than in *Felis*.

In 1901 Boule[4], in reviewing these forms, remarked that the absence of a downward symphysial expansion and the approximation in size between the upper and lower canines clearly separated them from *Machaerodus*, and he referred them all to *Felis*.

A series of mandibles found in the Tertiaries of India extending in age from the sarmatian to the top of the pontian and a maxilla from the sarmatian throw a certain amount of light upon the evolution of this peculiar type and seem to justify its generic separation from *Machaerodus* and *Felis*.

[1] Weithofer. Beitrage zur Kenntniss der Fauna von Pikermi bei Athen, *Beitr. z. Pal. Ost-Ung. Wien*, VI (1888), p. 233.
[2] Kaup, Ossemens foss. Darmstadt (1832). p. 21. Pl. 2, fig. 3.
[3] Kittl, Die fossile Sangethiere von Maragha, *Ann. k. k. naturhist. Hofmuseums*, Vienna, I (1886), p. 5.
[4] Boule, Revision des espèces Européennes de Machairodus, *Bull. Soc. Géol. France*, (4), I, (1901), p. 569.

The writer has already referred to the matter[1] and has proposed the new generic names of *Sivaelurus* for the maxilla and one of the mandibles which occupy the lowest stratigraphical position in the series and that of *Paramachaerodus* for the Indian mandibles of higher levels and the Pikermi, Maragha and Eppelsheim species of Weithofer, Kittl and Kaup respectively.

The study of these forms has suggested to me certain speculations as to their origin and subsequent history, which will however be better discussed when the various Indian specimens have been described, and the evidence has been brought forward for regarding them as representing continuous stages of evolution from *Sivaelurus chinjiensis* to *Paramachaerodus schlosseri* and *orientalis*.

PARAMACHAERODUS cf. SCHLOSSERI Weithofer, sp.

1888. *Machaerodus schlosseri* Weithofer Beitrage zur Kenntniss der Fauna von Pikermi bei Athen, *Beitr. z. Pal. Ost.-Ung. Wien*, VI, p. 233.

The first of the specimens under examination was obtained from the neighbourhood of Hasnot and although the precise locality of the specimen was not recorded by Sub-Assistant Vinayak Rao, who collected it, yet the character of the matrix makes it practically certain that it came from the Dhok Pathan zone and not from the Tatrot beds, which are also fossiliferous in the neighbourhood of Hasnot. This is a red ferruginous sandstone, which is plentiful at this horizon of the Middle Siwaliks. The specimen (G. S. I. No. D. 140) is a portion of the left mandibular ramus, broken off short immediately behind m_1, but showing well the front part as far as the symphysis.

Subsequently to the fossilization of the specimen the contour of the individual teeth has become considerably worn and the points of some of the cusps have been entirely destroyed. It is therefore fortunate that another specimen (G. S. I. No. D. 141) is in existence, which, though coming from another locality, near the village of Bahitta,[2] belongs to essentially the same horizon, being if anything slightly older. This is a little smaller and shows certain slight differences from the Hasnot mandible, both in respect of the depth of jaw and in the contour of the ramus in front of pm_3

[1] Pilgrim: The correlation of the Siwaliks with mammal horizons of Europe. *Rec. Geol. Surv. India*, XLIII (1913), pp. 291, 314.

[2] This village is marked in the map which accompanied the author's paper quoted above l. c., Pl. 27. (lat. 32° 47′; long. 73° 18′).

both on its upper and lower margin, which approximate to those of *Paramachaerodus sivalensis* and *Sivaelurus chinjiensis*.

I have, indeed, considered the question of referring it to a distinct species from the Hasnot mandible, but having regard to the variations which occur in the various mandibles referred to the one species *Paramachaerodus schlosseri*, it seems impracticable to separate the Bahitta specimen specifically from the others, unless one were to make two additional species at the same time. But in any case there can be little doubt that the structure of the teeth is the same in both mandibles, and it is therefore essential that they should be considered as supplementary to one another.

I have compared my specimen both with the figures which accompany Weithofer's description and also with original specimens of this species obtained by Dr. A. Smith Woodward from Pikermi and now in the British Museum, and find that the differences are so trifling as to be quite within the limits of individual variation. It may be observed that Weithofer distinguishes two types of jaw belonging to this species, while the British Museum specimen differs again slightly from both of them.

The dimensions of this specimen are tabulated on p. 154 alongside those of the Bahitta mandible, of the Pikermi specimen of *Paramachaerodus schlosseri* and the mandibles assigned to *Paramachaerodus sivalensis* and *Sivaelurus chinjiensis*.

The lower margin of the ramus is almost straight except for the slightest bowing midway between m_1 and pm_4. The depth of the ramus is little if at all less in its front than in its hinder part. In the Pikermi mandibles the depth diminishes slightly towards the front. The Bahitta specimen agrees with the Pikermi rather than with the Hasnot form. The passage from the lower edge to the front edge of the ramus is abrupt, the angle between them being precisely the same as in the case of the Pikermi mandibles of *Paramachaerodus schlosseri*. This portion of the Bahitta mandible is defective, but it is likely that it is very similar to the Hasnot specimen though rather more slender. The outer face of the ramus passes as abruptly into the front face, the two being separated by a prominent ridge so that the anterior surface of the ramus is concave. This agrees perfectly with the condition in *Paramachaerodus schlosseri*, though perhaps in the Pikermi species the ridge is slightly more pronounced. The upper border of the ramus ascends but slightly from pm_3 to the base of the canine and less so than either the specimens from Bahitta or Pikermi. The space between the inner margin of the canine and the symphysial suture is the same as in the Pikermi species, about 6 m.m. Two mental foramina are visible, one beneath pm_3 and the other beneath the diastema. Of these the latter is much the larger.

M_1 consists of two lobes separated by a moderately deep notch of which the posterior one is the longer. At the base of the latter in the Bahitta mandible is a minute, backwardly projecting heel precisely as in the Pikermi mandible. I have very little doubt that a similar feature is present in the Hasnot species although on account of breakage it cannot now be seen in my specimen.

In pm_4 the enamel on the postero-internal surface has been badly worn as well as the whole of the anterior portion of the tooth, but by comparison with the in some respects better preserved pm_4 of the Bahitta mandible we can arrive at its structure with but little chance of being in error. The primary cusp is much taller than either the ones in front of and behind it. It is probable that the anterior of these two cusps is weaker than the posterior one and less strong than it is either in the Pikermi mandible or that from Bahitta. This will account for the proportionately inferior length of pm^4 in the Hasnot mandible. Behind the posterior cusp is a well-marked cingulum, which is continued as a broad shelf on the postero-internal corner of the tooth. The existence of this shelf makes the diametter of the tooth much greater behind than in front. The shape of the tooth is here identical with that of the Pikermi mandible.

Pm_3 is rather smaller than pm_4 but is constructed on a similar plan. The anterior cusp is, however, very slightly pronounced, and the shelf internal to the posterior cusp is weaker than in pm_4. This tooth seems to differ in no respect from the corresponding tooth of the Pikermi species.

Another feature deserving of notice about pm_3 is the presence of a series of crenulations on the anterior edge of the tooth, which, though minute, are very distinct. These crenulations are not recorded in the case of the Pikermi mandible, but since a very small amount of wear might dispose of them it does not follow that they were not present originally in the species. Further their presence on pm^3 strongly predisposes us to assume that similar crenulations existed on the canine, and this in its turn is suggestive both of the Machaerodonts and of the upper canine of *Paramachaerodus orientalis*, which shows them plainly.

The canine in my specimen appears by its root to have been a moderately large, slender tooth with a posterior ridge. It is larger than the canine in Weithofer's mandibles but equal in size to that of the British Museum specimen from Pikermi, which I have examined.

In conclusion the only certain differences between the Indian mandibles and that of *Paramachaerodus schlosseri* of Pikermi are the following :—

(1) The symphysial ridge seems to be slightly weaker in the Indian form ;

(2) The proportionate length of the premolars is rather different in the Indian mandibles, pm_4 being proportionately shorter. Since the British Museum specimen comes half way between the Indian mandibles and those figured by Weithofer, it seems difficult to make a specific distinction on this character.

The amount of the diastema behind the canine lies between that of Weithofer's mandibles A and B, while that in the British Museum specimen is the largest of all. The ratio of the diameter of the lower canine to the length of the diastema is the same in the Hasnot mandible as it is for Weithofer's mandible A, though less than in either of the other two specimens. The Bahitta mandible agrees with the two mandibles which have this ratio larger.

Since the species appears to be variable in these characters, whatever the explanation may be, it is quite impracticable to establish another species for the Hasnot or Bahitta mandibles distinct from that to which the three Pikermi mandibles have been assigned. At the same time, considering the imperfect state of preservation of the Indian specimens, I hesitate, until further material is obtainable, to give to them the unqualified appellation of *Paramachaerodus schlosseri*.

PARAMACHAERODUS SIVALENSIS Lyd. sp.

1877. *Pseudaelurus sivalensis*, Lydekker, *Rec. Geol. Surv. India*, Vol. X, p. 83.

1884. *Aelurogale sivalensis*, Lydekker, Indian Tertiary and post-Tertiary Vertebrata, *Pal. Ind.*, ser. 10, vol. II, p. 317, Pl. XLIV, fig. 7.

1913. *Sivaelurus* (?) *sivalensis*, Pilgrim, The correlation of the Siwaliks with mammal horizons of Europe, *Rec. Geol. Surv. India*, Vol. XLIII, pp. 282, 291.

The mandible which is the type of this species has already been admirably described and figured by Lydekker, and little need be added to this except conclusions as to its generic position, based entirely on specimens which were not discovered when Lydekker wrote his description. Considering the fragmentary nature of the mandible Lydekker's determination of it as *Aelurogale* (=*Aelurictis*) was the soundest possible in the circumstances, and Matthew's reference of all species of *Aelurictis* to the genus *Nimravus* removes any generic significance which might have attached to certain features in which this mandible differs from European species of *Aelurictis*, since these species are now merged in the genus *Nimravus*, other species of which do not exhibit these distinctions.

The very close affinity which this mandible undoubtedly shows to the species of *Paramachaerodus* which have just been described, enables us to infer the existence of certain characters in the mandible now under consideration which are not actually visible. The most important of these concerns the structure of the hinder portion of m_1. If we compare the lobes and alveoli of m_1 in the present mandible and that from Bahitta, it seems impossible to imagine that the heel of this tooth was much more pronounced in the former specimen than it is in the latter. That it may have been a little stronger in *Paramachaerodus sivalensis* is possible, but it cannot, I think, have approached the dimensions which it exhibits in all species of *Nimravus*, including those referred formerly to *Aelurictis*. It is not, perhaps, possible to assert positively that a vestigial m_2 was absent, but that it fulfilled any function is extremely unlikely, considering the entire absence of any trace of a root behind m_1. It seems most probable that this tooth was entirely absent, as is the case in the mandible of *Paramachaerodus* cf. *schlosseri* from Bahitta.

The greater length of the premolars in this mandible as compared with the carnassial is certainly a distinction between it and all species of *Nimravus*.

It seems also allowable to attach some value as evidence to the fact that two mandibles to which this shows distinct affinity, namely that of *Paramachaerodus schlosseri* and that of *Sivaelurus chinjiensis* may reasonably be associated with maxillæ, which are obviously distinct generically from *Nimravus* not only by their shortness and absence of a diastema between pm_2 and the canine, but also by the presence both of a parastyle and an anterior cingular cusp to the upper carnassial.

There seems no need to consider in any further detail the differences of this mandible from other genera. Those generic distinctions which separate the genus *Paramachaerodus* from other genera apply equally in this case. It is necessary, however, to mention my reason for assigning it to *Paramachaerodus* rather than to *Sivaelurus*, which was my first opinion. I was at first inclined to attach considerable importance to the presence both in this mandible as well as in that of *Sivaelurus chinjiensis* of a vestigial pm_2. The investigations of Matthew and others have, however, shown that the mere presence or absence of vestigial teeth is an inconstant feature and often individual. Under these circumstances the mere fact that a pm_2 is present in both these mandibles and absent in those from Bahitta and Hasnot should not be regarded as a valid reason for necessarily placing the two former into the same genus, and the two latter into another. At the same time the long diastema in Lydekker's specimen points to an affinity with the Chinji mandible, and there seems little doubt both that the former represents a stage intermediate between *Sivaelurus* and *Paramachaerodus* and also that other species, still undiscovered, might easily so bridge over the interval that separates them, as to render generic separation extremely difficult. Since the Chinji mandible is so fragmentary, many important characters which might have afforded a means of distinction are unknown to me. I rely therefore upon the following as indicating a generic difference between it and Lydekker's species :—

(1) The very small dimensions of pm_2 and the very different proportions between pm_3 and pm_4;

(2) the entirely different appearance of the front portion of the jaw due to the much larger angle which the front surface of the mandible makes with the lower surface. This causes the canine to project forward in the most striking degree. In both of these points Lydekker's species does not differ essentially from either of the mandibles of *Paramachaerodus schlosseri*.

It remains to detail the particulars in which this species is to be distinguished from the other forms of *Paramachaerodus*.

(1) The ramus is decidedly shallower, though, if anything, stouter in proportion than in any of the forms referred to *Paramachaerodus schlosseri*.

(2) The diastema is proportionately longer than in any other species of *Paramachaerodus*, even in the British Museum specimen, in which it is longer than the others. The

ratio between the length of the diastema and the antero-posterior diameter of the canine ranges in *Paramachaerodus schlosseri* from 1.2 to 1.5 but in the present mandible this ratio is as high as 1·62.

(3) A vestigial pm_2 is present about 9 mm. in front of pm_3.

(4) The space left for the incisors between the canine and the symphysis is more confined than in *Paramachaerodus schlosseri.*

(5) The upper margin of the ramus slopes upward between pm_3 and the canine more steeply than is generally the case in the other forms, although the Bahitta mandible and that of *Paramachaerodus ogygia* considerably minimize this distinction.

SIVAELURUS CHINJIENSIS Pilgrim

1910.—*Pseudaelurus chinjiensis*, Pilgrim, Notices of new mammalian genera and species from the Tertiaries of India, *Rec. Geol. Surv. India*, vol. XL, p. 65.

1913.—*Sivaelurus chinjiensis*, Pilgrim, The correlation of the Siwaliks with mammal horizons of Europe, *Rec. Geol. Surv. India*, vol. XLIII. pp. 314 footnote and 291.

The type of this genus and species is a right maxilla (G. S. I., No. D. 150), which I formerly referred to the genus *Pseudaelurus*. It was found in the Chinji horizon of the Lower Siwaliks in the neighbourhood of Chinji, and has attached to it some of the characteristic red concretionary sandstone of the Chinji beds. The maxilla appears to be almost complete, the specimen showing in addition the broken base of the jugal and the anterior margin of the orbit.

The height of the maxilla is about 52 mm. and the length 51.6 mm. The distance between the infraorbital foramen and the front edge of the maxilla is 24 mm. and the height of the orbital margin above the crown base of pm^3 is 28 mm.

These dimensions together with those of the teeth are tabulated below :—

	Height of maxilla	52
	Length of maxilla	51·6
	Distance between infraorbital foramen and front edge of maxilla	24
	Height of orbital margin above base of pm^3 . . .	28
M^2	length	4·6
	breadth	11·2
Pm^4	length	20·6
	breadth	9·2

Pm^3	length	11·5
	breadth	6·2
Pm^2	length	3·9(?)
	breadth	1·7(?)
C	anteroposterior diameter	11·0
	transverse diameter	7·8

Pm^2 is a one rooted, probably functionless tooth, of which the alveolus completely fills up the space between pm^3 and the canine so that there is no diastema.

Pm^3 consists of a tall principal cusp, a distinct metastyle and a rudimentary parastyle. Behind is a heel which passes into a faint cingulum on the postero-internal half of the tooth. It is noteworthy that on the anterior blade of the principal cusp there are quite distinct traces of serrations, which no doubt were once much stronger. There certainly seems to be some significance in the fact that similar serrations exist on pm_3 of the Chinji mandible referred to this species and on the corresponding tooth in the Hasnot mandible of *Paramachaerodus* cf. *schlosseri*.

Pm^4 consists of a principal cusp (paracone), an elongated hinder shear (metacone), a well marked anterior cusp (parastyle) and a fairly strong inner cusp (protocone) on a level with and separated by a distinct broad valley from the parastyle. On the blade of the paracone a series of striae may be seen which obviously are the remains of serrations corresponding to those referred to above in the case of pm_3. A small but clearly defined cusp lies in front of and external to the parastyle, which seems to be homologous with the anterior cusp developed in some of the Machaerodonts and may be known as an anterior cingular cusp. There is a cingulum on the internal side of the metacone.

M^1 is a transversely elongated tooth, its long diameter forming a little less than a right angle with the axis of the carnassial and the tooth series. It consists of an external elongated transverse blade and an internal cusp.

The canine which is broken off at the base of the crown is a perfectly elliptical tooth, compressed transversely but without any indication of a posterior ridge.

The cat-like features of this maxilla are apparent at a glance, while the large, transversely elongated m^1 and the small pm^3 equally bespeak its primitive constitution.

Although in some respects this maxilla reminds one of *Pseudaelurus*, yet the following distinctions are amply sufficient to justify generic separation :—

(1) The entire absence of a diastema anywhere in the tooth series;
(2) The inferior size of pm^3 in *Sivaelurus* and the lesser prominence of the postero-internal cingular shelf;
(3) The smaller size of the canine in *Sivaelurus*, its entirely elliptical shape in cross section and the absence of the posterior trenchant edge which the canine of *Pseudaelurus* possesses;
(4) The presence of a strong antero-external cingular cusp in pm^4;
(5) The greater depth and lesser length of the maxilla in *Sivaelurus*.

Sivaelurus differs from *Nimravus*, so far as the maxilla is concerned :—

(1) by the presence of a strong parastyle and antero-external cingular cusp in pm^4;
(2) by the smaller pm^3;
(3) by the absence of a diastema;
(4) by the greater transverse diameter of m^1;
(5) by the weaker protocone in pm^4.

These points serve equally to distinguish *Sivaelurus* from *Aelurictis*, placed by Matthew in the genus *Nimravus*.

Sivaelurus differs from *Dinictis* :—

(1) by the presence of a parastyle and antero-external cingular cusp, and by the less prominent protocone in pm^4;
(2) by the more robust canine.

Hoplophoneus may be distinguished from the Indian genus :—

(1) by its rudimentary parastyle;
(2) by the larger pm^2;
(3) by the exceedingly slender canine;
(4) by the lesser transverse elongation of m^1.

Sivaelurus differs from *Felis* in the following particulars :—

(1) the larger dimensions and the transversely elongated shape of m^1. A slight approach to this is seen in a few modern cats such as *Felis temminckii* of Sikkim, but the difference is still marked and indicates an earlier and more primitive constitution.

(2) The shortness of pm^3 distinguishes *Sivaelurus* from most species of *Felis*, but in *Felis caracal* this tooth is equally short.

(3) The presence of a pronounced antero-external cingular cusp in pm^4. In *Felis caracal* an evidently homologous structure exists, but faintly and in quite a rudimentary condition. A similar but also rather rudimentary cusp is found in pm^4 of *Felis brevirostris* of the Middle Pliocene. It appears also that such an anterior cusp is found in the upper milk carnassial of *Felis spelaea*, from which we may infer that its presence is primitive and that it atrophied later.

(4) The larger upper canine, which, though elliptical in cross section like *Felis*, more resembles the Machaerodont canine than that of any known cat.

Cryptoprocta, although possessing a very similar m^1 to *Sivaelurus*, is distinguished by the completeness of the premolar series, apart from other more or less obvious features.

Machaerodus, equally with *Felis*, differs from *Sivaelurus* by the small m^1, while pm^3 is even smaller as compared with the carnassial than in the Chinji maxilla. Other still more obvious differences are the rudimentary nature of the protocone in pm^4 and the larger canine.

Coming to *Paramachaerodus* as represented by the maxilla of *Paramachaerodus orientalis* from Maragha, one cannot fail to be struck by the resemblances, allowing for its greater size, between it and *Sivaelurus*. The structure and proportionate dimensions of pm^3 and pm^4 are almost identical, the anterior cingular cusp only differing in the Maragha maxilla by being situated a little more internally. Both forms have equally short muzzles; the diastema between pm^3 and the canine in *Paramachaerodus orientalis* represents the exact equivalent of the space filled by pm^2 in *Sivaelurus*. The upper canine is even larger in the Maragha than in the Chinji species and has the trenchant edge which appears to be lacking in the latter species. The transversely elongated m^1 and the existence of pm^2, though amply sufficient to justify generic separation, are merely ancestral characters which one might expect to find in a sarmatian or tortonian form and to disappear in its pontian descendant. The depth of the maxilla is also proportionately greater in the Chinji than in the Maragha specimen.

Mandible.—The mandible now to be described (G. S. I., No. D 151) is merely referred provisionally to the species *Sivaelurus chinjiensis.* It was found in the same beds and agrees well in size with the type maxilla. At the same time it is extremely fragmentary, and it is just possible that the hinder portion might contradict the deductions as to its affinities which I draw from its anterior portion.

It is broken off behind pm_4 and the front half of the latter tooth is broken off nearly level with the root. The specimen is figured in Pl. 2, figs. 2,2a, 2b, and its various dimensions are given in the table on page 154.

Pm_4 is a rather long tooth, with a strong metastyle behind the principal cusp and an equally pronounced cingulum developed behind and on both sides of the metastyle, but decidedly broader internally. In *Paramachaerodus* this cingulum is chiefly developed on the internal side, but there is little if any difference between the proportionate breadth in the front and hinder portions of the tooth as compared with *Sivaelurus.* There is room for a slight parastyle in front of the principal cusp, but it is impossible to say whether such was present or not.

Pm_3 is a small tooth with a metastyle behind the principal cusp and an encircling cingulum similar to but weaker than that on pm_4. The tooth however tapers behind, unlike pm_4 and unlike the corresponding tooth in *Paramachaerodus.* There is no parastyle. The front edge of the blade of this tooth shows a very distinct series of fine serrations, which recall those on the teeth of the maxilla just described.

About half way between pm_3 and the canine is the alveolus of a small pm_2, which was evidently functionless. The upper margin of the ramus ascends between pm_3 and the canine. The lower margin of the ramus passes abruptly into the front surface in a precisely similar way to what is the case in *Paramachaerodus,* only differing by the smaller departure from the horizontal, the angle between the two surfaces being about 59° as against 65° in *Paramachaerodus* cf. *schlosseri* and *Paramachaerodus sivalensis.* A ridge of about the same strength as the corresponding ridge in *Paramachaerodus* cf. *schlosseri* separates the lateral surface from the front surface of the ramus. The root of the canine is elliptical in cross section without the distinct indication of a posterior trenchant edge which is found in *Paramachaerodus* cf. *schlosseri.* The space between the inner margin of the canine and the symphysial suture is about the same as in

Paramachaerodus sivalensis and less than it is in *Paramachaerodus* cf. *schlosseri*. The actual symphysis is also longer than seems to be the case in either of the mandibles of *Paramachaerodus*. There are two mental foramina, of which the anterior one is the larger and is situated beneath the diastema, while the posterior one lies beneath pm_3.

It will thus be seen that the anterior portion of this mandible agrees in shape with the various mandibles referred to *Paramachaerodus*. These all differ equally from *Pseudaelurus* as from *Felis* by the presence of a symphysial ridge and by the abrupt passage from the under to the front surface of the ramus. It is true that similar characters are found in *Nimravus*, but the long symphysis and the forward inclination of the front portion of the ramus is unlike that genus. Moreover the small size of pm_3 in comparison with pm_4 is unlike any known species of *Nimravus*.

Machaerodus, and the Machaerodont phylum generally, agree in respect to the small size of pm_3 but may easily be distinguished by the descending symphysial flange and by the smaller lower canine.

The points in which this Chinji mandible differs from the mandibles of *Paramachaerodus* from Pikermi, Bahitta and Hasnot are not inconsistent with an older form ancestral to the pontian species. The vestigial pm_2 is, obviously, a primitive feature, while the slenderness and shallowness of the ramus and the small size of pm_3 are characters found alike in Oligocene forerunners of both the Feline and Machaerodont phyla, such as *Dinictis* and *Hoplophoneus*. When in addition there is preserved to us such a mandible as that of *Paramachaerodus sivalensis*, which in most of these particulars is intermediate between the sarmatian and pontian forms and serves to bridge the interval, we have strong evidence that the Chinji mandible is closely allied to the actual ancestor of *Paramachaerodus*.

The affinity between the maxilla of *Sivaelurus chinjiensis* and that of *Paramachaerodus orientalis* from Maragha has already been noted. There seems strong reason to suppose that the Chinji maxilla belongs to an animal which was closely allied to the actual ancestor of the Maragha species. There seems equally strong reason for associating the mandible of *Paramachaerodus schlosseri* at least generically with the Maragha maxilla. Zittel[1] and Schlosser[2] even identify the two specimens specifically, but in any case the proportions existing between

[1] Zittel, Handbuch der Palæontologie, Vol. IV, p. 674.

[2] M. Schlosser, Die Affen, etc. des Europäischen Tertiärs, *Beitr. z. Pal. Öst-Ung. Wen*, VIII (1890), p. 52.

the diastema in the mandible and the upper canine, the crenulated canines in both and the general correspondence between the two teeth series justify us in considering them as generically the same.

Assuming that the Chinji mandible is ancestral to *Paramachaerodus schlosseri* and that the Chinji maxilla represents a correspondingly earlier stage on the line leading to *Paramachaerodus orientalis*, it seems useless to refrain from provisionally uniting the two Chinji specimens specifically. The close agreement in size and the serrations on the edges of the premolars in both, furnish additional arguments in favour of this decision.

The Phylogeny of Sivaelurus and Paramachaerodus.

W. D. Matthew in his paper on the Phylogeny of the Felidæ[1] has very clearly set forth the evidence for the existence of two perfectly distinct lines in this group .—

(1) the Machaerodonts, originating from the Oligocene *Hoplophoneus*;

(2) the Felines originating from the Oligocene *Dinictis*.

In the former line Matthew supposes that progressive enlargement of the upper canine has been accompanied by progressive reduction of the lower canine. The inner cusp of the upper carnassial has aborted gradually, and pm^3 in the upper jaw and pm_3 in the lower jaw are reduced. In the Feline line progressive reduction in the upper canine and progressive enlargement in the lower canine has taken place, the internal cusp of the upper carnassial remains strong, pm^3 in the upper jaw is large while pm_3 in the lower jaw enlarges to subequality with pm_4. It may be added that, according to this theory of descent, while the downward symphysial expansion is present in the earliest known members of both lines, in the Feline line this disappears although a symphysial ridge remains in the Miocene *Nimravus*, which vanishes in *Pseudaelurus* and *Felis*. In the Machaerodont line, on the contrary, the symphysial expansion tends to strengthen, up to the final extinction of the line with the Sabre-tooths of the Pleistocene.

Matthew, however, has not entered into the exact relations between the upper Miocene members of the Feline line and the genus *Felis*, nor has he remarked upon the presence at such a late date as the pontian of forms like *Paramachaerodus schlosseri* and *orientalis*, which, while possessing a large pm_3, still retain a symphysial ridge and moderately large upper canines. Equally has he

[1] *Bull. Amer. Mus. Nat. Hist.*, XXVIII (1910), pp. 289—316.

offered no explanation of the origin of certain short-faced species of *Felis* which have a small pm^3 and pm_3, like *Felis brevirostris* of the Pliocene and the recent *Felis caracal*, or of such a form as the recent *Felis nebulosa*, in which not only is pm_3 small, but also a certain squareness of chin is distinctly traceable, while the size of the upper canines exceeds that of any other known modern species of *Felis*. In the hope that the material, now described for the first time, may throw some little light on the answer to this and kindred problems, and may indicate the lines on which further palæontological discoveries and research may eventually succeed in completely elucidating it, I am tempted to offer a few tentative remarks on the subject.

Assuming that the evidence detailed above is sufficient to justify us in connecting *Sivaelurus* through the intermediate links of *Paramachaerodus sivalensis* and variants of *Paramachaerodus schlosseri* with *Paramachaerodus orientalis* of Maragha, the origin of *Sivaelurus* first claims our attention. Can we place it on the one or the other of Matthew's two main groups of Machaerodonts or Felines or can we ascertain its relations to the main line of development in either case as stated by that author? An endeavour will be made by selecting for comparison with *Sivaelurus* those forms on either line which we have reason to regard as representing synchronous or at all events equivalent stages of development. The sarmatian (possibly tortonian) age of *Sivaelurus* is the first consideration; next the absence of a descending flange to the symphysis provides us with definite proof of a stage much later than that of *Dinictis* and *Hoplophoneus*. Therefore we may, perhaps, compare the Indian genus with Miocene types of *Machaerodus* and *Nimravus*. We need only to notice the large m^1 of *Sivaelurus*, the prominent protocone of its pm^4, the absence of any exceptional enlargement of the upper canine or of the upper carnassial as well as of a descending flange to the symphysis to convince us that the genus can find no place on the Machaerodont line of evolution. On the other hand in all these respects it conforms to the Feline line. It obviously represents a stage as primitive as that of *Pseudaelurus* and *Nimravus*, judging by its large m^1 and the absence of any great degree of reduction in the dentition. *Sivaelurus* like *Paramachaerodus* shows by the absence of a descending flange to the symphysis and the larger lower canine a considerable advance on *Dinictis*, though it is not possible to assert positively that like the Middle Siwalik forms, *Sivaelurus* has lost all vestiges of an ancestral metaconid in m^1, this portion of the mandible being unknown in the latter genus.

On the other hand, when consideration is taken of its short muzzle, the short diastema in the upper dentition, the small size of pm_3 and the large upper canine and carnassial, one is disposed to regard it as representing the outcome of a branch of evolution parallel to that which led to the genera *Nimravus* and *Pseudaelurus*, and taking its origin as far back as the genus *Dinictis*, some species of which, somewhat allied to *D. squalidens*, might not have been far removed from the hypothetical Oligocene ancestor of *Sivaelurus*, if we accept Matthew's phylogenetic theory. As in the case of *Nimravus*, the descending flange of the symphysis has disappeared, but the remnant of it remains in the abrupt passage of the chin into the lower margin of the ramus and the expansion of this portion of the jaw.

In the course of the evolution of this type into that of *Paramachaerodus*, the chief changes which have taken place are the equalization in size of the carnassial and the premolars, the shortening of the diastema in the lower dentition and the reduction in size of the upper molar.

The history of this line in the Pleistocene is unknown, and there seems reason to think that the type of *Paramachaerodus* itself has left no descendants in modern times. This belief is based on the failure to find, at all events amongst species, sufficiently large to be descended from *Paramachaerodus schlosseri* and *orientalis*, such a combination of characters as are met with in these pontian species. Even though the angularity of chin may have been on the way to disappearance, still such modern species as have an equally large upper canine differ in the relations of size existing between the carnassial and the premolars.

In the common Indian and Malay species *Felis nebulosa*, we find many peculiar features in the mandible and in the dentition which are shared by the sarmatian *Sivaelurus*, but by no other living species. *Felis nebulosa* possesses a larger upper canine than in any other species of *Felis*. This tooth has also a sharp trenchant posterior edge. Although the skull is elongated, the muzzle is short. The mandible is characterized by a long diastema between the canine and pm_3, in which a vestigial pm_2 often exists; pm_3 is very small compared to pm_4 and the carnassial; m_1 has a distinct talon; while occasionally on the carnassial as well as the canine I seem to see a faint vestige of a former crenulation of the blade. Last of all the chin passes more abruptly into the basal margin of the ramus than I have found to be the case in other species of *Felis*. The species is much the same size as *Sivaelurus chinjiensis*, but the height of the maxilla is greater in the latter, the muzzle is shorter in proportion and the upper carnassial is proportionately larger. Still it seems to me possible that *Felis nebulosa* may be descended from some such form as *Sivaelurus*, though no doubt the hypothetical ancestor was of inferior dimensions to the species *Sivaelurus chinjiensis*.

I do not propose to enter into the history of the genus *Felis*, but would merely suggest that the differences between the various modern species of cat are too great to lend much support to the theory of the monophyletic origin of the genus, or to render it likely that *Nimravus* or *Pseudaelurus* is to be regarded as the common ancestor of them all. The discovery of *Sivaelurus*, which reveals what we suspect to be a direct connection between *Felis nebulosa* and a sarmatian ancestral type may but herald that of numerous other phyla which evolved on parallel lines.

Measurements of mandibles of Paramachaerodus and Sivlaeurus.

—	Paramachaerodus scholsseri(A) (Weithofer Pl. 11 fig. 5—7).	Paramachaerodus schlosseri (B) (Weithofer Pl. 11 fig. 3, 4).	Paramachaerodus schlosseri (Brit. Mus. No. M. 8959).	Paramachaerodus cf. schlosseri (Hasnot, G. S. I. No. D. 140).	Paramachaerodus cf. schlosseri Bahitta, (G. S. I. No. D. 141.)	Paramachaerodus sivalensis (G. S. I. No. D. 95).	Sivaelurus chinjiensis (G. S. I. No. D. 151).
M_1 length	21·3	..	21·7	22·5	19·5	21·0	..
M_1 breadth	9·0	..	..	9·0	7·7	8·7	..
Pm_4 length	18·8	18·6	18·8	18·5	17·3	17·5	13·8
Pm_4 breadth in front	6·5	..	..	6·8	5·9	..	5·1
Pm_4 breadth behind	8·4	..	8·6	8·6	8·3	..	6·9
Pm_3 length	12·7	12·5	3·3	14·0	13·0	13·3	8·2
Pm_3 breadth in front	..	..	..	..	..	..	..
Pm_3 breadth behind	6·1	6·3	..	7·4	..	..	4·5
C antero-posterior diameter	11·4	11	13·7	13·7	12·1	11·8	11·0
C transverse diameter	7·3	..	..	8·3	..	8·2	6·7
Diastema between C and Pm_3	13·5	179·0	19·3	16·3	17·0	19·1	18·8
Depth of jaw below m_1	27	..	27	27	26·0	24 8	32·0
Depth of jaw in front of Pm_3	24·5	25·5	..	27	22·5	23·5	21·9
Maximum thickness of jaw below M_1	13	..	..	12.0	11.8	12.2	10·7
$\frac{\text{Length of } Pm_4 \times 100}{\text{Length of } Pm_3}$	148	148	141	132	133	131	168
$\frac{\text{Diastema between C and } Pm_3 \times 100}{\text{Length of C}}$	118	154	141	119	140	162	171

EXPLANATION OF PLATES.

PLATE 5.

FIG. 1.—*Paramachaerodus* cf. *schlosseri* Weith. sp. left mandibular ramus, 1 surface view 1a external side view. From the middle Siwaliks of Hasnot, Punjab (G. S. I. No. D. 140) Page 139

FIG. 2.—*Paramachærodus* cf. *schlosseri* Weith. sp. left mandibular ramus, 2 surface view 2a external side view. From the Middle Siwaliks of Bahitta, Punjab (G. S. I. No. D. 141) Page 139

All figures natural size.

PLATE 6.

FIG. 1.—*Sivaelurus chinjiensis* Pilg. right maxilla, 1 surface view 1a external side view. From the Lower Siwaliks of Chinji, Punjab (G. S. I. No. D. 150) Page 145

FIG. 2.—*Sivaelurus chinjiensis ?* Pilg. left mandibular ramus front portion, 2 surface view, 2a external side view, 2b internal side view. From the Lower Siwaliks of Chinji, Punjab (G. S. I. No. D. 151) Page. 149

All figures natural size.

ERRATUM.

Page 241, column 4, line 10, *for* $(33\bar{5}1)$ *read* $(5 \cdot 5 \cdot \overline{10} \cdot 2)$.

Page 246, lines 6 and 7 from bottom, for n read η.

RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

Part 3.] 1915. [October

HERBERT STANLEY BION.

IT is with great regret that I have to record the death, on June 6th, at the age of 27, of Mr. H. S. Bion, Assistant Superintendent, Geological Survey of India. Although he joined the Department so recently as January 18th, 1911, Mr. Bion had already shown that he was a geologist of no ordinary ability. Trained in London under Professor E. J. Garwood, his bent lay chiefly towards the palæontological and stratigraphical aspects of his subject, and on these he was mainly employed, although he also took his share of current economic investigations. During his association with Mr. Middlemiss in the geological survey of Kashmir, his ready grasp of the most difficult stratigraphical problems gave promise of a brilliant future, and his subsequent work in Burma, both scientific and economic, showed that he possessed, in addition to ability, conscientiousness and perseverance. He had, in fact, all the qualities which go to make a geologist of the first order.

During his short term of service, his attractive disposition endeared him to all his colleagues, and through his untimely death every member of the Geological Survey has to deplore the loss not only of a brilliant collaborator but also of a warm personal friend.

H. H. HAYDEN.

THE MINERAL PRODUCTION OF INDIA DURING 1914. BY H. H. HAYDEN, C.I.E., F.R.S., *Director, Geological Survey of India.*

CONTENTS.

I.—INTRODUCTION.

THE method of classification adopted in the first Review of Mineral Production published in these *Records* (Vol. XXXII), although admittedly not entirely satisfactory, is still the best that can be devised under present circumstances. The methods of collecting the returns are becoming more precise every year and the machinery employed for the purpose more efficient. Hence the number of minerals included in Class I—for which approximately trustworthy annual returns are available—is gradually increasing, and it is hoped that before long the minerals of Class II—for which regularly recurring and full particulars cannot be procured—will be reduced to a very small number. In the case of minerals, such as tin-ore, still exploited chiefly under primitive native methods and thus forming the basis of an industry carried on by a large number of persons each working independently and on a very small scale, the collection of reliable statistics is impossible, but the total error from year to year is not improbably approximately constant and the figures obtained may be accepted as a fairly reliable index to the general trend of the industry. In the case of gold, the small native alluvial industry contributes such an insignificant portion to the total outturn that any error from this source may be regarded as negligible.

Total value of production.

Table 1 shows the values of the production of minerals for which returns are obtainable. It has not been customary hitherto to include in this table such materials as building stones, road metal, and clay, since the returns are incomplete. To omit them altogether, however, is even more misleading than to include the returns in their imperfect state, and as the value is not inconsiderable, the figures have been added to the table; they probably represent less than half the actual production of those materials.

TABLE 1.—*Total Value of Minerals for which Returns of Production are available for the years 1913 and 1914.*

Mineral.	1913.	1914.	Increase.	Decrease.	Variation per cent.
	£	£	£	£	
Coal	3,798,137	3,907,380	109,243	..	+ 2·9
Gold	2,291,917	2,338,355	46,438	..	+ 2·0
Petroleum	1,034,586	958,565	..	76,021	— 7·3
Manganese-ore (*a*)	1,211,034	877,264	..	333,770	— 27·6
Salt (*b*)	541,447	483,289	..	58,158	— 10·7
Saltpetre	200,803	272,462	71,659	..	+ 35·7
Mica (*c*)	347,451	237,310	..	110,141	— 31·7
Building materials and road metal.	243,493	214,421	..	29,072	— 11·9
Lead and lead-ore	113,023	202,330	89,307	..	+ 79·0
Tungsten-ore	127,762	178,543	50,781	..	+ 39·7
Ruby, sapphire and spinel.	55,542	43,133	..	12,409	— 22·3
Monazite	42,012	41,411	..	601	— 1·4
Iron-ore	39,680	40,665	985	..	+ 2·5
Jadestone (*c*)	24,093	40,092	15,999	..	+ 66·4
Tin-ore and tin	46,401	38,203	..	8,198	— 17·7
Silver	15,338	26,896	11,558	..	+ 75·4
Zinc-ore	4,871	10,762	5,891	..	+ 120·9
Copper-ore	8,650	7,294	..	1,356	— 15·7
Garnet	1,288	4,806	3,518	..	+ 273·1
Alum	3,794	4,649	855	..	+ 22·5
Steatite	6,700	4,131	..	2,569	— 38·3
Chromite	2,435	2,611	176	..	+ 7·2
Clay	2,744	2,567	..	177	— 6·5
Gypsum	1,071	979	..	92	— 8·6
Diamond	1,791	791	..	1,000	— 55·8

(*a*) Value f.o.b. at Indian ports.
(*b*) Prices without duty.
(*c*) Export values.

TABLE 1.—*Total Value of Minerals for which Returns of Production are available for the years 1913 and 1914*—contd.

Mineral.	1913.	1914.	Increase.	Decrease.	Variation. per cent.
	£	£	£	£	
Magnesite . . .	4,776	557	..	4,219	— 88·3
Corundum . . .	2,215	447	..	1,768	— 79·8
Amber . . .	29	274	245	..	+ 844·8
Platinum . . .	324	213	..	111	— 34·3
Agate . . .	250	175	..	75	— 30
Ochre . . .	919	157	..	762	— 82·9
Samarskite . .	7	121	114	..	..
Bauxite . . .	33	32	..	1	— 3·0
Asbestos . . .	..	23	23	..	..
Pitchblende . .	..	13	13	..	..
Triplite . . .	..	13	13	..	..
Total .	10,174,616	9,940,934	406,818	640,500	— 2·3
			—233,682		

There has been a small decrease in the value of production in 1914 as compared with the preceding year. This is due mainly to the serious depression in the manganese market which has resulted in a fall in the value of production of over £300,000 or more than 27 per cent. The production of mica has also fallen by nearly 32 per cent., while petroleum and salt also show decreases of about 7 and 11 per cent., respectively. On the other hand there have been considerable increases in the production of lead (79 per cent.), wolfram (40 per cent.) and saltpetre (36 per cent.), while the value of the outputs of coal and gold respectively have risen 3 and 2 per cent., respectively.

Mineral concessions granted.

The number of licenses and leases granted during the year amounted to 363 as against 495 in 1913.

II.—MINERALS OF GROUP I.

Chromite.	Iron-ore.	Manganese-ore.	Platinum.	Saltpetre.
Coal.	Jadeite.	Mica.	Ruby, Sapphire and Spinel.	Tin-ore.
Diamonds.	Lead-ore.	Monazite.		Tungsten-ore.
Gold.	Magnesite.	Petroleum.	Salt.	Zinc-ore.

Chromite.

There was a slight rise, amounting to rather less than 4 per cent., in the output of chromite in the year 1914 over that of the previous year. As will be seen from table 2, the output both of Baluchistan and of Bihar and Orissa fell to a slight extent, but the increase in Mysore more than compensated for the loss elsewhere.

TABLE 2.—*Quantity and Value of Chromite produced in India during 1913 and 1914.*

—	1913.		1914.	
	Quantity.	Value.	Quantity.	Value.
	Tons.	£	Tons.	£
Baluchistan	3,414	1,162	3,006	1,052
Bihar and Orissa	848	452	552	301
Mysore	1,414	821	2,330	1,258
Total .	5,676	*2,435*	5,888	*2,611*

Coal.

There was a small rise of 1½ per cent. in quantity, and about 3 per cent. in value, of the Indian output of coal, which has now reached nearly 16½ million tons with a value of £3,907,380. The pit's mouth value varied from Rs. 3 in Central India to Rs. 9-9 in Baluchistan, the figures for the chief coalfields, however, being Rs. 3-3-4 for the fields of Bihar and Orissa and Rs. 3-13-10 for those of Bengal. There has been a very marked rise in recent

There was a considerable increase in the output of the Bihar and Orissa fields, amounting to over 400,000 tons, but a decrease of over 225,000 tons in Bengal. With the exception of Baluchistan and Rajputana, all other provinces show an increase in output.

The percentage of coal produced by the Tertiary coalfields to the total output was only 2·58; it was, however, a little higher than in the previous year. The chief Tertiary coalfield is still that of Margherita, the output of which rose from a little over 270,000 tons to nearly 304,000.

TABLE 7.—*Provincial Production of Coal during the years 1913 and 1914.*

Province.	1913.	1914.	Increase.	Decrease.
	Tons.	Tons.	Tons.	Tons.
Assam	270,862	305,160	34,298	..
Baluchistan	52,932	48,234	..	4,698
Bengal.	4,649,985	4,424,557	..	225,428
Bihar and Orissa . . .	10,227,557	10,661,062	433,505	..
Central India	148,978	152,906	3,928	..
Central Provinces . . .	235,651	244,745	9,094	..
Hyderabad	552,133	555,991	3,858	..
North-West Frontier Province	90	94	4	..
Punjab	51,040	54,303	3,263	..
Rajputana (Bikaner) . .	18,781	17,211	..	1,570
Total .	**16,208,009**	**16,464,263**	*487,950*	*231,696*

TABLE 8.—*Output of the Gondwana Coalfields for the years 1913 and 1914.*

Coalfields.	1913.		1914.	
	Tons.	Per cent. of Indian Total.	Tons.	Per cent. of Indian Total.
Bengal, Bihar and Orissa—				
Daltonganj	85,345	·53	81,680	·50
Giridih	806,810	4·98	825,026	5·01
Jherria	8,608,310	53·11	9,146,653	55·55
Bokaro-Ramgarh . .	3,319	·04	16,920	·15
Rajmahal	3,572		8,145	
Raniganj	5,327,248	32·87	4,946,295	30·04
Sambalpur (Hingir-Rampur).	42,805	·26	60,883	·37
Darjeeling District (non-act).	133	..	17	..

TABLE 8.—*Output of the Gondwana Coalfields for the years 1913 and 1914*—contd.

Coalfields.	1913.		1914.	
	Tons.	Per cent. of Indian Total.	Tons.	Per cent. of Indian Total.
Central India—				
Umaria	148,978	·92	152,906	·93
Central Provinces—				
Ballarpur	80,959	·50	89,292	·54
Pench Valley . .	89,805	·55	95,679	·58
Mohpani	64,887	·40	59,774	·37
Hyderabad—				
Singareni	552,133	3·41	555,991	3·38
Total .	**15,814,304**	**97·57**	**16,039,261**	**97·42**

TABLE 9.—*Output of Tertiary Coalfields for the years 1913 and 1914.*

Coalfields.	1913.		1914.	
	Tons.	Per cent. of Indian Total.	Tons.	Per cent. of Indian Total.
Assam—				
Makum	270,364		303,890	
Naga Hills	..	1·67	778	1·86
Khasi and Jaintia Hills .	498		492	
Baluchistan—				
Khost	45,585	·28	39,557	·24
Sor Range, Mach, etc. .	7,347	·05	8,677	·05
North-West Frontier Province—				
Hazara	90		94	
Punjab—				
Jhelum	46,155	·31	45,867	33
Mianwali	..		1,557	
Shahpur	4,885		6,879	
Rajputana—				
Bikaner	18,781	·12	17,211	·10
Total .	**393,705**	**2·43**	**425,002**	**2·58**

The total number of persons employed in the coalfields rose from 144,966 in 1913 to 151,376 in the year under review. The output per person employed, however, was smaller than it had been in recent years, having been only 108·76 tons. Altogether there were 170 fatal accidents, indicating a death-rate of 1·12 per thousand persons employed.

TABLE 10.—*Average number of persons employed daily in the Indian Coalfields during 1913 and 1914.*

Province.	Number of persons employed daily.		Output per person employed.	Number of deaths by accidents.	Death-rate per 1,000 persons employed.
	1913.	1914.	1914.	1914.	1914.
Assam . . .	2,478	2,888	105·66	16	5·54
Baluchistan . .	1,087	1,001	48·18	5	4·99
Bengal . . .	38,561	38,882	113·79	41	1·05
Bihar and Orissa .	87,452	90,855	117·34	78	·85
Central India . .	1,593	3,038	50·33	1	·32
Central Provinces .	2,684	3,254	75·21	3	·92
Hyderabad . .	10,028	10,141	54·82	24	2·36
North-West Frontier Province.	6	7	13·43	..	..
Punjab . . .	892	1,161	46·77	2	1·72
Rajputana (Bikaner) .	185	149	115·51	..	..
Total .	**144,966**	**151,376**	..	**170**	..
Average . . .	..	..	*108·76*	..	*1·12*

Diamonds.

There was a further decline in the output of diamonds, which fell from 115·7 carats in 1913 to 54·65 carats, valued at £791, in the year under review. The attempts to work diamonds in the Madras Presidency seem to have been given up.

TABLE 11.—*Quantity and Value of Diamonds produced in India during 1913 and 1914.*

—	1913.		1914.	
	Quantity.	Value.	Quantity.	Value.
	Carats.	£	Carats.	£
Central India	78·70	1,769	54·65	791
Madras	37	22	..	..
Total .	**115·70**	*1,791*	**54·65**	*791*

Gold.

The output of gold rose by about 2 per cent. The increase is chiefly due to the Anantapur mines in Madras, the output of which increased by nearly 9,000 ozs., the increase in the Mysore mines being about 3,000 ozs.; there was a decline of nearly 1,700 ozs. in the output from the Myitkyina district, the dredging operations at Myitkyina not being so successful as had been hoped.

TABLE 12.—*Quantity and Value of Gold produced in India during 1913 and 1914.*

—	1913.		1914.		Labour.
	Quantity.	Value.	Quantity.	Value.	
	Oz.	£	Oz.	£	
Burma—					
Myitkyina . .	5,329·77	20,412	3,635·60	13,905	159
Katha and Pakokku	20·31	100	12·59	67	
Upper Chindwin .	43·45	255	45·60	268	
Shwebo . . .	..	..	10·55	55	
Hyderabad . . .	20,012·4	77,228	21,200	80,479	1,775
Madras . . .	11,019	43,194	19,873	82,959	2,038
Mysore . . .	559,197·98	2,150,194	562,355	2,159,604	26,290
Punjab . . .	134	517	249·98	994	470
United Provinces .	4·2	17	5·75	24	35
Total .	**595,761·11**	*2,291,917*	**607,388·07**	*2,338,355*	**30,767**

Iron.

There was a further increase in the total amount of iron-ore produced, which rose from nearly 371,000 tons in 1913 to nearly 442,000 in the year under review. Singhbhum increased its out-turn by over 50 per cent., whilst the outputs in Burma and the Central Provinces rose by about 8,000 and 15,000 tons respectively. The increase in the production of iron-ore in Burma was due to more active smelting operations conducted by the Burma Corporation at Bawdwin. The output of iron and steel amounted to 234,726 tons of pig-iron and 66,603 tons of steel including 45,659 tons of steel rails, the latter produced by the Tata Iron and Steel Company.

TABLE 13.—*Quantity and Value of Iron-ore produced in India during 1913 and 1914.*

—	1913.		1914.	
	Quantity.	Value.	Quantity.	Value.
	Tons.	£	Tons.	£
Bengal—				
Burdwan	8,926	1,278	1,204 *	171
Bihar and Orissa—				
Singhbhum	98,196	10,898	151,662·3	15,083
Orissa	247,081	23,125	249,958	16,674
Other Districts	610	281	617	278
Bombay	·5	..	·75	..
Burma	11,480	3,061	19,482	5,195
Central India	418	111	326·5	59
Central Provinces	3,774	830	18,402	3,198
Hyderabad	249	66	..	..
Rajputana	97·5	26	..	..
United Provinces	13	4	21·7	7
Total	**370,845**	*39,680*	**441,674·25**	*40,665*

* Decrease in output is due to the Ramnagore Colliery areas being under water for part of the year.

Jadeite.

The condition of the jadeite industry in Burma is still far from satisfactory, although the output, which had fallen in 1913 to 3,281 cwt., was nearly trebled in 1914, rising to 9,925 cwt. The increase in quantity, however, was not accompanied by a corresponding rise in the value of the output, which increased only from £12,780 in 1913 to £12,976 in the year under review. This was due no doubt to the production of inferior material. On the other hand, exports of jadeite by sea decreased by 2 cwt. from 2,961 cwt. in 1913 to 2,959 in 1914, while the value of the latter was £40,092 as against only £24,903 in the previous year. Evidently, therefore, the price of jadeite has risen very considerably, and the value returned for the output for 1914 shows either that the value was understated, or else that the material being won is so inferior that the industry will soon become too unprofitable to be continued. In view, however, of the great rise in the export value, it seems more probable that the value has been grossly understated by the miner.

Lead.

There was a very marked increase in the output of lead-ore and slag from the Bawdwin mines in 1914, the output of ore rising from 3,939 tons in 1913 to 8,769 tons in the year under review. The amount of slag treated also rose from 16,360 tons to 24,901 tons. The slag heaps left by the old Chinese miners are gradually becoming exhausted, and in a short time this source of lead will no longer be available. The output of ore however, has increased considerably, and ore-bodies of great size are said to have been proved. The amount of lead extracted was 10,548 tons in 1914 as against 5,858 tons in the preceding year. The estimated value of the production of lead is based on the market value of that metal during the year, and the values given in the tables do not represent the pit's mouth value of the ore and slag. These materials being treated on the spot, it is impossible to assess their value accurately, and it seems preferable to base estimates of the value of the output on the market price of lead.

The Bawdwin slag and ore also yielded 236,446 ozs. of silver in 1914 as against 125,209 ozs. in the preceding year.

In the processes of mining with Bawdwin ores a considerable amount of zinc-ore was recovered, the chief ore-bodies being composed of intimate mixtures of zinc-blende and galena. The figures showing the amount of zinc-ore won will be found on page 179.

TABLE 14.—*Production of Silver-lead-ore during 1913 and 1914.*

—	1913.			1914.		
	Quantity.	Value.		Quantity.	Value.	
	Lead-ore and slag.	Lead-ore and lead.	Silver.	Lead-ore and slag.	Lead-ore and lead.	Silver.
	Tons.	£	£	Tons.	£	£
Burma—						
Northern Shan States.	3,939 (ore)	49,374(*a*)	10,585	8,769 (ore)	27,346(*d*)	13,039
	16,360 (slag)	63,563(*b*)	4,753	24,901 (slag)	174,933(*e*)	13,857
Southern Shan States.	24·27	65	..	12	32	..
Central Provinces—						
Drug . .	1·5	21	..	3·25	19	..
Total .	**20,324·77**	*113,023*	*15,338*(*c*)	**33,685·25**	*202,330*	*26,896*(*f*)

(*a*) Value of 2,561 tons of lead extracted.
(*b*) Value of 3,297 tons of lead extracted.
(*c*) Value of 125,209 ozs. of silver extracted.
(*d*) Value of 1,426 tons of lead extracted.
(*e*) Value of 9,122 tons of lead extracted.
(*f*) Value of 236,446 ozs. of silver extracted.

Magnesite.

There was a very marked fall in the outturn of magnesite, which fell from over 16,000 tons in 1913 to a little less than 1,700 tons in the year under review. This was chiefly due to a decrease in the output from the Chalk Hills, which fell from 14,086 tons, valued at £14,153, to 399 tons, valued at £130. There was also a fall in the output from Mysore from 2,112 tons valued at £623, to 1,281 tons valued at £427.

Manganese.

The manganese-ore industry has suffered from severe depression during the year 1914, the output having fallen from 815,047 tons valued at £1,211,034 in 1913 to 682,898 tons in 1914, valued at £877,264.

TABLE 15.—*Quantity and Value of Manganese-ore produced in India during 1913 and 1914.*

—	1913.		1914.	
	Quantity.	Value f. o. b. at Indian ports.	Quantity.	Value f. o. b. at Indian ports.
	Tons.	£	Tons.	£
Bihar and Orissa—				
Gangpur . . .	11,215	16,168	6,070	7,613
Bombay—				
Chota Udepur . .	..	..	7,735	9,701
Panch Mahals . .	40,914	58,984	19,488	24,441
Central India—				
Jhabua	6,814	8,461	6,642	6,144
Central Provinces—				
Balaghat . . .	219,139	336,926	221,159	296,722
Bhandara . . .	89,818	138,095	82,055	110,090
Chhindwara . . .	78,583	120,821	87,114	116,878
Nagpur . . .	261,767	402,467	174,562	234,204
Madras—				
Sandur	52,169	62,385	33,643	29,858
Vizagapatam . . .	44,127	52,769	26,375	23,408
Mysore	10,501	13,958	18,055	18,205
Total .	**815,047**	*1,211,034*	**682,898**	*877,264*

Mica.

During 1914, the outturn of mica was about 5,000 cwt. lower than that during the previous year, while the value of the output fell from over £115,000 to £88,000. The chief fall was in Madras, where the output fell nearly 50 per cent. On the other hand, there was a slight increase in the output of the Koderma mines in Bihar and Orissa; the increase in output, however, in that province was accompanied by a fall in value of about £16,000, while the total amount of mica exported fell from 62,474 cwt. valued at £347,451 in 1913 to 40,502 cwt. valued at £237,310 in 1914.

TABLE 16.—*Quantity and Value of Mica produced in India during 1913 and 1914.*

			1914.	
				Value.
	Cwt.	£	Cwt.	£
Bihar and Orissa	32,579	62,624	33,275	46,796
Madras	11,200	47,494	5,989·5	36,140
Rajputana	1,953	5,102	1,192·1	4,968
Mysore	29	109	50	186
Total .	**45,761**	*115,329*	**40,506·6**	*88,090*

Monazite.

The output of monazite from Travancore State was 1,185·65 tons valued at £41,411 in 1914 as against 1,234·75 tons valued at £42,012 in 1913.

Petroleum.

It is very rarely that we have to record a fall in the output of petroleum, which rose from 118½ million gallons in 1904 to over 277 million in 1913. In 1914, however, production fell to a little over 259 million gallons. The output of 1913 had marked a very considerable increase on all previous years, while the output for the year under review is still more than 10 million gallons higher than that for the year 1912. The total value of the output for 1914 was £958,565 as against £1,031,586 in 1913. There was a considerable decrease in the output from the Yenangyaung field, which fell from over 200 million gallons in 1913 to about 175 million gallons in the year under review On the other hand, there was an increase of about 10 million gallons in the output of the Singu field, while both Yenangyat and Minbu show considerable decreases. The output of the Digboi fields in Assam was almost exactly the same in 1914 as in the preceding year. Recent prospecting operations in the Punjab have resulted in the discovery of what is believed to be a promising field in the neighbourhood of Pindigheb to the north of the Salt Range. Hitherto all attempts to exploit oil in the Punjab have been unsuccessful, owing chiefly to the unfavourable structure and disturbed conditions of the Tertiary rocks. The structure of the Pindigheb area, however, is said to be highly favourable to the retention of oil.

The amount of paraffin wax exported rose from 272,226 cwt. valued at £401,857 in 1913 to 362,678 cwt. valued at £1,534,740 in the year under review.

TABLE 17.—*Quantity and Value of Petroleum produced in India during 1913 and 1914.*

—	1913.		1914.	
	Quantity.	Value.	Quantity.	Value.
	Gallons	£	Gallons.	£
Burma—				
Akyab	14,023	270	12,918	249
Ky•ukpyu	29,251	821	25,987	777
Magwe (Yenangyaung)	200,555,668	771,962	171,981,799	673,525
Myingyan (Singu)	63,538,710	211,829	73,109,518	241,698
Pakokku (Yenangyat)	5,499,191	20,731	1,516,685	16,729
Minbu	3,198,311	13,326	1,683,190	7,013
Thayetmyo	30,240	168	22,836	95
Assam—				
Digboi (Lakhimpur)	4,688,628	15,466	4,688,547	15,466
Punjab—				
Mianwali	1,200	13	1,200	13
Total	**277,555,225**	*1,021,586*	**259,342,710**	*958,565*

There was a considerable increase in the imports of kerosene into India during the year, the total being nearly 84 million gallons as against only 66 million gallons in 1913.

TABLE 18.—*Imports of Kerosene oil during 1913 and 1914.*

—	1913.		1914.	
	Quantity.	Value.	Quantity.	Value.
	Gallons.	£	Gallons.	£
From—				
Borneo	16,995,348	429,889	26,966,642	661,243
Persia	2,710,458	85,855	2,765,685	81,237
Roumania	1,413,639	29,451	..	..
Russia	1,934,221	123,826	1,661,870	43,662
Straits Settlements (including Labuan).	3,061,404	79,186	5,553,268	147,183
United States.	37,392,084	1,048,122	46,931,641	1,328,352
Other Countries	252,651	6,369	428	15
Total	**66,759,805**	*1,802,998*	**83,879,534**	*2,261,692*

Platinum.

36·69 ozs. of platinum, valued at £213, were won during the course of the gold dredging operations at Myitkyina. This constitutes a decrease on the outturn of the previous year, which was 57·68 ozs. valued at £324.

Ruby, Sapphire and Spinel.

The output of the Ruby Mines shows a slight increase in quantity, but a considerable fall in value. As will be seen from Table 19, the weight of rubies won fell by about 10,500 carats, while there was a rise of nearly 35,500 carats in the output of sapphires.

Table 19.—*Quantity and Value of Ruby, Sapphire and Spinel produced in India during 1913 and 1914.*

	1913.		1914.	
	Quantity.	Value.	Quantity.	Value.
	Carats.	£	Carats.	£
Burma—				
Mogok	203,925 (Rubies)	50,944	193,333 (Rubies)	40,781
Do.	21,353 (Sapphires)	4,028	56,709 (Sapphires)	2,052
Do.	53,428 (Spinels)	570	54,830 (Spinels)	300
Total .	278,706	*55,542*	304,872	*43,133*

Salt.

There was a slight decrease in the output of salt, which fell from 1,473,189 tons valued at £511,447 in 1913 to 1,348,225 tons valued at £483,289 in 1914. The outturn of rock-salt amounted to 156,550 tons. There was also a decrease of the imports of salt, which fell from 590,431 tons to 562,018 tons. Imports from the United Kingdom fell by nearly 40,000 tons, from Germany by 20,000 tons, from Asiatic Turkey by 10,000 tons, and from Spain by 5,000 tons. On the other hand, there were appreciable rises in imports from Aden and Egypt.

TABLE 20.—*Quantity and Value of Salt produced in India during 1913 and 1914.*

	1913.		1914.	
	Quantity.	Value.	Quantity.	Value.
	Tons.	£	Tons.	£
Aden	173,908	69,402	144,463	57,636
Bengal	25	4	6	2
Bombay and Sind	467,578	109,877	486,898	113,453
Burma	30,109	102,034	21,522	75,536
Gwalior State	114	310	99	271
Kashmir	73	46	73	55
Madras	348,287	115,292	298,862	115,494
Northern India	453,095	144,182	396,302	120,842
Total	**1,473,189**	*511,147*	**1,348,225**	*483,289*

TABLE 21.—*Quantity and Value of Rock Salt produced in India during 1913 and 1914.*

	1913.		1914.	
	Quantity.	Value.	Quantity.	Value.
	Tons.	£	Tons.	£
Salt Range	138,542	17,775	135,519	19,113
Kohat	19,099	1,896	18,239	1,810
Mandi	3,542	4,218	2,792	3,325
Total	**161,183**	*23,889*	**156,550**	*24,218*

TABLE 22.—*Quantity and Value of Salt imported into India during 1913 and 1914.*

	1913.		1914.	
	Quantity.	Value.	Quantity.	Value.
	Tons.	£	Tons.	£
From				
Aden and Dependencies .	124,908	115,955	153,163	146,790
Egypt . . .	86,853	82,299	93,775	100,263
Germany . . .	55,124	65,123	35,014	40,174
Spain	73,514	66,299	68,273	64,538
Turkey, Asiatic . .	72,266	66,920	62,255	60,896
United Kingdom . .	140,728	140,192	103,038	104,395
Other Countries . .	37,038	33,669	46,500	42,299
Total	590,431	570,457	562,018	559,355

Saltpetre.

The amount of saltpetre produced in India during the year 1914 was nearly 15,500 tons valued at over £272,000 as against a little less than 11,500 tons valued at over £200,000 in 1913. This shows an increase of nearly 36 per cent. On the other hand, the exports decreased from 15,235 tons in 1913 to 14,157 tons in the year under review, the decrease in value being over £4,500. There was a considerable change in the distribution of the exports, nearly half of the total quantity going to the United Kingdom, thus constituting an increase of more than 100 per cent. on the amount taken by that country in previous years. There was, however, a considerable decrease in the exports to China and to the United States, and a slight decrease in those to Mauritius.

TABLE 23.—*Quantity and Value of Saltpetre produced in India during 1913 and 1914.*

—	1913.		1914.	
	Quantity.	Value.	Quantity.	Value.
	Tons.	£	Tons.	£
Bihar	5,342	71,844	4,896	76,946
Bombay (Cutch)	3	26	1	11
Central India	24	208	..	..
North-West Frontier Province	7·5	247	2·2	51
Punjab	2,964	56,433	3,520	73,401
Rajputana	363	3,197	405·9	1,232
United Provinces	5,758	68,848	6,664	117,818
Total	**14,461·5**	*200,803*	**15,489·1**	*272,462*

TABLE 24.—*Distribution of Saltpetre exported during 1913 and 1914.*

—	1913.		1914.	
	Quantity.	Value.	Quantity.	Value.
	Cwt.	£	Cwt.	£
Ceylon	43,813	30,177	44,085	28,674
China	80,574	65,277	49,266	40,305
Mauritius and Dependencies	38,200	27,714	23,406	17,778
United Kingdom	56,430	44,651	125,918	111,076
United States of America	50,920	40,149	19,163	15,096
Other Countries	34,755	29,613	21,298	19,987
Total	**304,692**	*237,581*	**283,136**	*232,916*

Tin.

While the value of tin and tin-ore produced in Burma fell from over £46,000 in 1913 to a little over £38,000 in the year under review, there was a small increase in the imports during the same period. Owing, however, to the lower price of tin in 1914, the value of the quantity imported in that year was nearly £80,000 less than that of a similar quantity imported in the preceding year.

There has been an increase in the amount of tin-ore produced in the Southern Shan States. The chief producer, however, is still the Tenasserim Division, Mergui and Tavoy contributing more than three-fourths of the total production.

Table 25.—*Quantity and Value of Tin and Tin-ore for the years 1913 and 1914.*

	1913.				1914.			
	Block Tin.		Tin-ore.		Block-Tin.		Tin-ore.	
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.
	Cwt.	£	Cwt.	£	Cwt.	£	Cwt.	£
Bihar and Orissa—								
Hazaribagh .	1	17	..	..	1	16	..	..
Burma—								
Mergui . .	2,336	24,419	1,717	7,703	1,963	16,235	1,861	9,263
Southern Shan States.	..	..	1,675	5,861	..	..	2,767	8,993
Tavoy . .	1,314	8,279	21	122	..	..	767	3,696
Total .	**3,651**	*32,715*	**3,413**	*13,686*	**1,964**	*16,251*	**5,395**	*21,952*

Table 26.—*Imports of Tin, unwrought (blocks, ingots, bars and slabs), into India during 1913 and 1914.*

	1913.		1914.	
	Quantity.	Value.	Quantity.	Value.
	Cwt.	£	Cwt.	£
From United Kingdom . .	5,336	59,042	5,113	40,806
,, Straits Settlements (including Labuan).	35,209	371,532	35,340	312,318
,, Other Countries . .	95	1,057	254	1,969
Total .	**40,640**	*431,631*	**40,707**	*355,093*

Tungsten.

The output of wolfram in Burma rose from 1,688 tons valued at £127,762 in 1913 to 2,326 tons valued at £178,543 in the year under review. Had it not been for temporary dislocation of the arrangements for disposing of ore during the latter part of last year, the output would probably have been considerably higher. The industry, however, subsequently recovered itself, and, owing to the demand for wolfram for the manufacture of tungsten-steel, the year 1915 should be an extremely prosperous one so far as this industry is concerned. The greater part of the output comes from Tavoy, while Mergui shows a slight falling off, and the Southern Shan States (Mawchi) a slight increase. A new source of wolfram appears for the first time, *viz.*, Thaton district to the north of Tavoy, whence 17 tons were obtained.

TABLE 27.—*Quantity and Value of Tungsten-ore produced in Burma during 1913 and 1914.*

—	1913.		1914.	
	Quantity.	Value.	Quantity.	Value.
	Tons.	£	Tons.	£
Burma—				
Mergui	205·5	17,092	191	16,647
Southern Shan States .	83·7	5,861	138·4	8,993
Tavoy	1,399	104,809	1,976·6	152,333
Thaton	..	..	17	570
Total . .	1,688·2	*127,762*	2,326	*178,543*

Zinc.

The Burma Corporation produced from their Bawdwin mines 8,553 tons of zinc-ore valued at £10,762 as against 3,871 tons, valued at £4,871, produced during the year 1913. The ore is found in association with galena in the Bawdwin mines, large ore-bodies being composed of the latter mineral and zinc-blende.

III.—MINERALS OF GROUP II.

Agate. 101 tons of agate, valued at £175, were won in the Rajpipla State during the year.

Alum. There was a slight rise in the output of alum from 7,842 cwt. valued at £3,794 in 1913 to 8,731 cwt. valued at £4,649 in the year under review. Nearly the whole of this output was derived from the Salt Range.

Amber. The output of amber was still insignificant, being only 13 cwt. in 1914 as against 10 cwt. in the preceding year. The quantity however was better and the value was £274, or about £21 per cwt., as against £29 or rather less than £3 per cwt.

Asbestos. A small quantity (about 5 tons) of asbestos was won in the Hassan district of Mysore, but the total output was valued at only £23.

Bauxite. 511 tons of bauxite were produced as against 1,184 in the previous year. The value, however, was estimated at only £1 less, *viz.*, £32 as against £33 for the larger quantity. Bauxite is used in the manufacture of cement at Katni.

Building stones. The value of building-stone and road-metal produced during the year 1914 was £214,121 as against £213,493 in the previous year (see table 28). These figures, however, only represent a fraction of the total output. It has been found impossible to obtain reliable returns.

Clay. The production of clay is returned at 54,710 tons valued at £2,567 as against 47,422 tons valued at £2,744 in 1913. The figures are very incomplete, and probably do not represent even the twentieth part of the total production.

Copper. 5,324 tons of copper ore, valued at £7,294, were won during the year as against 3,810 tons, valued at £8,650 during the preceding year. Almost the whole of this came from the Cape Copper Company's mines in Singhbhum.

Corundum. There was a marked fall in the output of corundum from 8,924 cwt. valued at £2,215 in 1913 to 2,360 cwt. valued at £147 during the year under review.

TABLE 28.—*Production of Building Materials and Road Metal in India during the year 1914.*

	GRANITE.		LATERITE.		LIME		LIMESTONE AND KANKAR.		MARBLE		SANDSTONE.		SLATE.		TRAP.		MISCELLANEOUS.	
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.
	Tons.	£	Tons.	£	Tons.	£	Tons	£	Tons.	£	Tons.	£	Tons.	£	Tons.	£	Tons.	£
Assam	..	..	..	..	..	..	108,431	9,418	..	..	..	.	..	..	..	..	..	..
Baluchistan	..	..	..	..	..	..	212	395	.	..	..	..	..	..	..	..	..	..
Bengal	..	..	..	..	..	..	6	1	..	..	..	.	.	..	..	..	..	..
Bihar and Orissa.	20,114	3,777	3,067	41	..	..	239,297	24,061	..	..	28,014	2,221	2,600	2,907	16,423	1,043	241,396	13,723
Burma	108,711	8,506	166,377	14,095	..	..	185,802	10,068	..	..	163,246	7,420	..	..	..	..	382,675	32,887
Central India	..	..	..	..	..	..	35,240	1,556	..	..	.	..	..	..	..	..	..	..
Central Provinces.	..	..	..	..	..	..	148,471	12,012	..	..	..	..	..	..	..	..	430	25
Hyderabad	..	..	..	..	..	..	..	..	..	..	..	..	Not known	1,428	..	..	..	..
Madras	76,226	1,465	93,630	3,035	..	..	65,169	2,529	..	..	..	..	..	..	..	..	94,719	6,243
North-West Frontier Province.	..	..	..	..	..	..	16,428	370	.	..	..	..	..	..	..	..	..	..
Punjab	..	..	..	..	..	..	30,818	2,178	..	..	60,818	6,371	9,831	7,870	..	..	3,762	59
Rajputana	..	..	..	..	..	.	4,675	170	3,044	2,230	39,292	12,577	..	..	..	..	6,810	271
United Provinces.	..	..	..	..	66	26	615	150	.	..	197,699	21,907	1,240	729	..	..	2,746	657
Total	**205,951**	*13,748*	**263,074**	*17,171*	**66**	*26*	**835,164**	*62,908*	**3,044**	*2,230*	**489,069**	*50,496*	**13,671**	*12,934*	**16,423**	*1,043*	**732,538**	*53,865*

Garnet. The output of garnet increased considerably from 334 cwt. valued at £1,288 to 21,906 cwt. valued at £4,806. Of this quantity Madras produced 21,440 cwt. valued at only £464, whereas the Kishengarh State produced 464 cwt. valued at £4,333. The latter State is the chief source of the garnet used in the manufacture of cheap jewellery in India.

Gypsum. The output of gypsum was much the same as in the preceding year, being 22,268 tons valued at £979 as against 24,961 tons valued at £1,071

Ochre. The production of ochre has fallen very considerably in recent years and the output now is quite insignificant, being only 608 tons valued at £157 during the year 1914. The output during the previous year was 5,067 tons valued at £919.

Pitchblende. A small quantity of pitchblende was won from the Singar Mine in the Gaya district. The total amount, however, was only 16 lbs. valued at £13.

Samarskite. 43 cwt. of samarskite, valued at £121, were recovered as against 3 cwt. valued at £7 in the year 1913. This comes from the Nellore mica mines.

Steatite. There was a very marked decrease in the production of steatite during the year under review, the total output being only 999 tons valued at £4,131 as against 2,524 tons valued at £6,700 in the preceding year. The decrease was most marked in Karnul in the Madras Presidency and in Hamirpur in the United Provinces.

TABLE 29.—*Quantity and Value of Steatite produced in India during 1913 and 1914.*

—	1913.		1914.	
	Quantity.	Value.	Quantity.	Value.
	Tons.	£	Tons.	£
Bihar and Orissa—				
Singhbhum	800	160	(*a*)	400
Seraikela	190	9	..	..
Mayurbhanj	66	200	60	173

(*a*) Quantity not returned.

TABLE 29.—*Quantity and Value of Steatite produced in India during 1913 and 1914*—contd.

	1913.		1914.	
	Quantity.	Value.	Quantity.	Value.
Central Provinces—				
Jubbulpore . . .	661	378	502	129
Hyderabad . . .	(*a*)	12	..	..
Madras—				
Bellary	14	1	25	2
Kurnool . . .	545	4,436	210	1,576
Nellore	20	52	60	715
United Provinces—				
Hamirpur . .	200	1,335	120	744
Jhansi	28	117	22	92
Total .	**2,524**	*6,700*	**999**	*1,131*

(*a*) Quantity not returned.

Triplite.

A small quantity—10 tons valued at £13—of triplite was produced during the year in the neighbourhood of Singar in the Gaya district of the province of Bihar and Orissa.

IV.—MINERAL CONCESSIONS GRANTED.

Table 30.—*Statement of Mineral Concessions granted during 1914.*

ASSAM.

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Khasi and Jaintia Hills.	(1) Mr. R. D. Coggan	Gold and certain other allied minerals.	P. L.	12,704	14th April 1914.	1 year.
Do.	(2) Do.	Tin and wolfram	P. L. (renewal).	12,704	Do.	Do.
Do.	(3) Do	Gold, tin and certain other allied minerals.	P. L. (renewal).	8,160	Do.	Do.
Do.	(4) Messrs. Tata Sons & Co.	Mineral oil	P. L.	7,040	31st October 1913.	2 years.
Lakhimpur	(5) Assam Oil Co., Ltd.	Oil	P. L.	5,546·6	12th January 1914.	1 year.

BALUCHISTAN.

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Kalat	(6) G. C. Whigham, Esq., Representative in India of the Burma Oil Co.	Oil	P. L.	6 different areas measuring 400,640 acres.	18th December 1914.	1 year.
Do.	(7) Mian Mohamed Ismail of Quetta.	Coal	M. L.	80	1st January 1914.	30 years.
Loralai	(8) K. S. Abdulla Asgar Alli.	Do.	M. L.	80	1st January 1915.	Do.
Quetta	(9) Mian Mohamed Ismail of Quetta.	Do	M. L.	80	1st January 1914.	Do.
Do.	(10) Do.	Do.	M. L.	28·40	1st July 1914.	Do.
Sibi	(11) Khan Bahadur B. D. Patel, C.I.E.	Do.	M. L.	80	Do.	Do.
Zhob	(12) Do.	Chromite	M. L.	80	1st January 1915.	Do.

BIHAR AND ORISSA.

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Hazaribagh	(13) Ananga Ranjan Chatarji.	Mica	M. L.	70	9th September 1913.	30 years.
Do.	(14) Babu Lakshmi Narain Sukhani.	Do.	P. L.	80	28th August 1914.	1 year.
Do.	(15) Messrs. F. F. Christien & Co.	Do.	P. L.	173·23	10th September 1914.	Do.

P. L. = *Prospecting License.* M. L. = *Mining Lease.*

BIHAR AND ORISSA—*concld.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Hazaribagh	(16) Sardar Govind Singh.	Mica	P. L.	320	13th October 1914.	1 year.
Do.	(17) Babu Lachmi Narain Shroff.	Do.	M. L.	6	15th September 1914.	30 years.
Do.	(18) Babu Sarada Prasanna Majumdar.	Do.	M. L.	120	27th November 1914	Do.
Sambalpur	(19) Mr. Thomas Pressick Yeoman.	Coal	P. L. (renewal)	1,300	27th November 1913	1 year.
Santal Parganas	(20) Binode Bihari De	Do.	M. L.	2	1st February 1914.	3 years.
Singhbhum	(21) Babu Krishna Chandra De of Calcutta	Manganese	P. L. (renewal)	249·6	18th July 1913	1 year.
Do.	(22) Mr. L. P. E. Pugh of Calcutta	Chromite	P. L.	3,136	5th June 1914	Do.
Do.	(23) The Indian Manganese Co., Ld., Nagpur	Manganese	P. L.	121·68	13th May 1914	Do.
Do.	(24) Rai Srinath Pal Bahadur of Calcutta.	Do.	P. L.	1,920	6th November 1914.	Do.
Do.	(25) Mr L. Laxman Rao Naidu of Nagpur.	Chromite	P. L.	1,621·18	16th October 1914	Do.
Do.	(26) Do	Do.	P. L.	927·38	Do	Do.

BOMBAY.

Panch Mahals	(27) The Bamankua Manganese Co., Ld.	Manganese	P. L.	530	1st January 1914	1 year.

BURMA.

Amherst	(28) Mr. S. E. Solomon	All minerals (except oil).	P. L.	2,240	23rd January 1914	1 year.
Do.	(29) Mr. L. Sisman	Do.	P. L. (renewal).	640	10th June 1914	Do.
Do.	(30) Mrs. M. M. Hla Oung	Do.	P. L. (renewal).	2,880	28th July 1914.	Do.
Do.	(31) Mr C. E Baw	Gold, silver, tin, copper, wolfram and antimony.	P. L. (renewal)	960	8th November 1914.	Do.
Katha	(32) Maung Nyo	Lead and silver	P. L. (renewal).	960	20th March 1914.	Up to 31st December 1914.
Lower Chindwin	(33) Messrs. The Burma Oil Co., Ltd.	Mineral oil	P. L. (renewal).	960	1st May 1914.	1 year.

P. L. = *Prospecting License.* M. L. = *Mining Lease.*

BURMA—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Lower Chindwin	(34) Mahomed Hussein and Jamal Bros. & Co.	All minerals (except oil).	P. L. (renewal).	1,440	1st August 1914.	1 year.
Magwe . .	(35) Messrs. The Indo-Burma Petroleum Co., Ltd	Mineral oil . .	P. L.	1,280 acres (Blocks 3 S. and 4 S.)	24th January 1914.	Do.
Do. . .	(36) Do .	Do. . .	P. L. .	1,280 acres (Blocks 5 S. and 6 S.)	14th February 1914.	Do.
Do. . .	(37) Do. .	Do. . .	P. L. .	1,280	18th March 1914.	Do.
Do. . .	(38) Do. .	Do. . .	P. L. (renewal).	640	12th November 1913.	Do.
Do. . .	(39) Ma Kin Le . .	Do. . .	P. L. (renewal).	383	7th November 1913.	Do.
Do .	(40) The Burma Oil Co., Ltd	Do. . .	P. L. (renewal).	2,240	19th February 1914.	Do.
Do. . .	(41) Maung Po Tan .	Petroleum . .	P. L. .	1,520	16th September 1914.	Do.
Mandalay .	(42) Mr. F. H. Parry .	Copper, lead and other minerals (except mineral oil).	P. L. .	640	6th February 1914.	Do.
Meiktila . .	(43) Mr. R. E. Smith .	Wolfram . .	P. L. .	3,200	7th March 1914.	Do.
Mergui . .	(44) Messrs. Bume and Reit.	All minerals (except oil).	P. L. .	435·20	29th January 1914.	Do.
Do. . .	(45) Do . .	Do . .	P. L. .	1,335·32	3rd January 1914.	Do.
Do .	(46) Maung Shwe Tha .	Do . .	P. L. . .	81·60	18th February 1914.	Do.
Do .	(47) Do .	Do . .	P. L. .	852·48	Do. .	Do.
Do . .	(48) M. E. Bhymeah .	Do. . .	P. L. (renewal).	2,135·04	9th February 1914.	Do.
Do. . .	(49) Maung Shwe I .	Do. . .	P. L. (renewal).	1,423·36	Do. .	Do.
Do . .	(50) C. Soo Don . .	Do. . .	P. L. (renewal).	381·44	Do. .	Do.
Do. . .	(51) Messrs. Bume and Reit	Do . .	P. L. (renewal).	547·84	29th January 1914.	Do.
Do. . .	(52) Do . .	Do. . .	P. L. (renewal).	2,862·08	Do. .	Do
Do. . .	(53) Maung Shwe Yaitt	Do. . .	P. L. (renewal).	2,406·20	1st November 1913.	Do.
Do. . .	(54) U Ne Gyi . .	Do. . .	P. L. (renewal).	3,000	6th December 1913.	Do.
Do. . .	(55) Maung Shwe Yaitt	Do. . .	P. L. (renewal).	2,304·00	21st December 1913.	Do.

P. L.=*Prospecting License.* M. L.=*Mining Lease.*

BURMA—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Mergui . .	(56) Maung Shwe Yaitt	All minerals (except oil)	P. L. (renewal).	714·56	21st December 1913.	1 year
Do. . .	(57) Maung Po Gyi .	Do. . .	P. L. (renewal).	3,159·04	12th February 1914.	Do.
Do. . .	(58) Lim Aw Kyi .	Do. . .	P. L. (renewal).	207·36	24th July 1913.	Do.
Do. . .	(59) U Shwe I . .	Do. . .	P. L. .	389·12	13th June 1914	Do.
Do. . .	(60) Mr. G. H. Hand	Do. . .	P. L. .	125·44	11th May 1914.	Do
Do. . .	(61) Messrs. Schröder Smidt & Co., Ltd.	Gold . . .	P. L. .	1,454·08	12th June 1914.	Do.
Do. . .	(62) Maung Shwe Don .	All minerals (except oil).	P. L. (renewal).	793·60	9th February 1914.	Do.
Do. . .	(63) Messrs. Bume and Reif.	Do. . .	P. L. (renewal).	1,236·32	10th November 1913	Do.
Do. . .	(64) Do. .	Do. . .	P. L. (renewal).	1,518·08	Do. .	Do.
Do. . .	(65) Maung Mya . .	Do. . .	P. L (renewal)	1,809·92	16th February 1914.	Do.
Do. . .	(66) Mr. J. Kinloch .	Do. . .	P. L. (renewal).	1,039·36	26th March 1914.	Do.
Do. . .	(67) Maung Po Thaik .	Do. . .	P. L. (renewal).	814·08	21st March 1914.	Do.
Do. . .	(68) Do. . .	Do. . .	P. L. (renewal) .	1,766·40	Do. .	Do.
Do. . .	(69) Maung Saw Maung	Do. . .	P. L. (renewal).	1,920	10th May 1914	Do
Do. . .	(70) G. S. Alweshwar .	Do. . .	P. L.	3,200	27th October 1913	Do.
Do. .	(71) Messrs. Moolla Dawood Sons & Co.	Do. . .	P. L. .	2,560	31st December 1913.	Do.
Do. . .	(72) Maung Saw Maung	Do. .	P. L. .	1,812·48	10th July 1914.	Do.
Do. . .	(73) G. Shwe Yin . .	Do. . .	P. L. .	1,002·52	21st July 1914.	Do.
Do. . .	(74) Maung Kyaw Din .	Do. . .	P. L. .	1,428·48	1st August 1914.	Do.
Do. . .	(75) The Great Tenasserim Coal Mining Syndicate, Ltd.	Coal . . .	P. L. .	2,362·88	15th August 1914.	Do.
Do. . .	(76) Messrs. Wightman & Co.	All minerals (except oil).	P. L. .	1,550	26th August 1914.	Do.
Do. . .	(77) Sit Kwet . .	Do. . .	P. L. .	1,373·28	24th July 1914.	Do.
Do. . .	(78) E. Ahmed . .	Do. . .	P. L. (renewal).	2,749·44	27th July 1914.	6 months.

P. L.=*Prospecting License.* M. L.=*Mining Lease.*

BURMA—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Mergui . .	(79) Saw Leng Lee .	All minerals (except oil).	P. L. (renewal).	660·48	2nd September 1914.	6 months
Do. . .	(80) Messrs. Moola Dawood Sons & Co.	Do. . .	P. L. (renewal).	3,140·63	24th September 1914.	1 year.
Do. . .	(81) E. Ahmed . .	Do. . .	P. L. (renewal).	2,316·80	30th October 1914.	6 months.
Do. . .	(82) Maung Ne Gyi .	Do. . .	P. L. (renewal).	3,200	6th December 1914.	Do.
Minbu . .	(83) Maung Saing .	Mineral oil . .	M. L. .	78·59	2nd March 1911.	30 years.
Do. . .	(84) Dadar Soomar .	Do. . .	P. L. .	355·84 acres(western half of 17R. southern portion of 17N. and northern portion of 18N).	30th January 1914.	1 year.
Do. .	(85) Captain H. Fenton	Do. . .	P. L. (renewal).	2,560	27th August 1913.	Do.
Do. . .	(86) Messrs. The British-Burma Petroleum Co., Ltd.	Do. . .	P. L. (renewal).	614·40	17th December 1913.	Do.
Do. . .	(87) Mr. H. P. Cameron	Do. . .	P. L. (renewal).	493 acres (Block 20P).	23rd October 1913.	Do.
Do. . .	(88) Maung Taik Gyi .	Do. . .	P. L. (renewal).	201	Do.	Do.
Do. . .	(89) Messrs. The Manset Co., Ltd.	Do. .	P. L. (renewal).	522·24	14th November 1913.	Do.
Do. . .	(90) Ellahi Buksh .	Do. . .	P. L .	860	21st February 1914.	Do.
Do. . .	(91) Maung Twa . .	Do. . .	P. L. .	640	11th April 1914.	Do.
Do. . .	(92) Maung Lu Pe .	Do. . .	P. L. .	1,920	22nd May 1914.	Do.
Do. . .	(93) Maung Ne Dun .	Do. . .	P. L. (renewal).	320	2nd May 1914	Do.
Do. . .	(94) Messrs. The British-Burma Petroleum Co., Ltd.	Do. . .	P. L. (renewal).	440·32	27th November 1913.	Do.
Do. . .	(95) Do. .	Do. . .	P. L. . (renewal).	174	20th November 1913.	Do.
Do. . .	(96) Do. .	Do. . .	P. L. . (renewal).	640	7th December 1913.	Do
Do. . .	(97) Maung Taik Gyi .	Do. . .	P. L. (renewal).	27·69	28th January 1914.	Do.

P. L.=*Prospecting License.* M. L.=*Mining Lease.*

BURMA—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Minbu . .	(98) Messrs. The Indo-Burma Petroleum Co., Ltd.	Mineral oil .	P. L. (renewal).	320]	28th January 1914.	1 year.
Do. . .	(99) Maung Tun Aung Gyaw.	Do. . .	P. L. (renewal).	1,290·54	28th February 1914.	Do.
Do. . .	(100) Abu Bucker .	Do. . .	P. L. .	960	27th July 1914	Do.
Do. . .	(101) Messrs. M. E. Bhymeah & Co.	Do . .	P. L. .	640	13th November 1913	Do.
Do. . .	(102) Maung Po Kin .	Do. . .	P. L. .	320 acres (western half of Block 11S. of the Minbu oil field).	14th October 1914.	Do.
Do. . .	(103) Messrs. M. E. Bhymeah & Co.	Do . .	P. L. (renewal).	640 acres (eastern half of Block 5N. and western half of Block 3S of the Minbu oil field)	13th November 1914.	Do.
Myingyan .	(104) British-Burma Petroleum Co., Ltd.	Do. . .	P. L. (renewal).	640 acres (Block 52N. in the Singu oil field).	12th July 1914	Do.
Do. . .	(105) Maung Tun Aung Gyaw.	Do. .	P. L. (renewal).	208·10	4th September 1914	Do.
Myitkyina .	(106) Mr. M. W. Halley	Gold . . .	P. L. .	4,940·8	8th January 1914	Do
Do. .	(107) Mr. D. L. Cramer .	Do . .	P. L. .	1,280	25th May 1914	Do.
Do. .	(108) Do. .	Do. . .	P. L. .	1,280	Do. .	Do
Do. .	(109) Do. .	Do. . . .	P. L. .	960	Do .	Do.
Do. .	(110) Mr. B. A. Baldwin	Gold, platinum and minerals of platinum group.	P. L. (renewal).	4,800	10th December 1913.	Do.
Do. .	(111) Mr. A. R. Oberlander.	Copper, silver and iron.	P. L. .	640	13th July 1914	Do.
Do. .	(112) Mr. B. A. Baldwin	Gold and allied minerals.	P. L. .	3,600	13th August 1914.	Do.
Northern Shan States.	(113) Hkun Hseng Awn	Lead, silver and allied metals.	P. L. (renewal)	640	11th March 1914.	Do.
Do. .	(114) Mr. A. R. Oberlander.	Gold, silver, lead, iron and zinc.	P. L. .	3,200	9th April 1914	Do.
Do. .	(115) Mr. L Borm .	Copper, galena and allied minerals.	P. L. .	2,560	23rd July 1914.	Do.
Do. .	(116) Saw Hke, Hsipaw Sawbwa.	Antimony, lead and silver.	P. L. .	2,560	25th November 1914.	Do.

P. L.=*Prospecting License.* M. L.=*Mining Lease.*

BURMA—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Pakókku .	(117) Mr. J. C. Cross .	Mineral oil . .	P. L. .	2,000	18th March 1914.	1 year.
Do. . .	(118) Messrs. The Burma Oil Co., Ltd.	Do. . .	M. L. . (renewal).	248·222 acres (State oil wells, Yenangyat).	1st October 1912.	Up to 31st July 1926.
Do. . .	(119) Messrs. The Indo-Burma Petroleum Co., Ltd.	Do. . .	P. L. . (renewal).	1,440 acres (eastern halves of Blocks 20 and 21 and certain adjoining area).	17th October 1913.	1 year.
Do. . .	(120) Messrs. The Nath Singh Oil Co., Ltd.	Do. . .	P. L. . (renewal).	1,920	24th January 1914.	Do.
Do. . .	(121) Messrs. The Indo-Burma Petroleum Co., Ltd.	Do. . .	P. L. . (renewal).	744·96 (east of Blocks 19, 20 and 21, Yenangyat).	8th March 1914.	Do.
Do. . .	(122) Messrs. The Burma Oil Co., Ltd.	Do. . .	P. L. .	Block D 2 in Yenangyat.	24th July 1914.	Do.
Do. . .	(123) Messrs. The Nath Singh Oil Co., Ltd.	Do. . .	P. L. . (renewal).	12,960	7th February 1913.	2 years.
Do. . .	(124) Messrs. The Burma Oil Co., Ltd.	Do. . .	P. L. . (renewal).	2,560	22nd July 1914.	1 year.
Do. . .	(125) Messrs. The Indo-Burma Petroleum Co., Ltd.	Do. . .	P. L. (renewal).	1,440 acres (eastern halves of Blocks 20 and 21, Yenangyat).	17th October 1914.	Do.
Do. .	(126) Messrs. The British-Burma Petroleum Co., Ltd.	Do. .	P. L. . (renewal).	614·40	23rd July 1914.	Do.
Do. . .	(127) Do .	Do. . .	P. L. . (renewal).	261	Do. .	Do.
Do. . .	(128) The Myaing Petroleum Syndicate.	Do. . .	M. L. .	850	1st July 1913	30 years.
Do. . .	(129) Messrs. The Nath Singh Oil Co., Ltd.	Do. . .	P. L. .	3,840	28th October 1914.	1 year.
Do. . .	(130) The Singu Burma Oil Syndicate.	Do. . .	P. L. .	Two pieces of land measuring 76·80 acres and 371·20 acres.	14th November 1914.	Do.
Prome . .	(131) Maung Gyi . .	Do. . .	P. L. . (renewal).	1,862·4	5th March 1914.	Do.
Shwebo . .	(132) Messrs. The Indo-Burma Petroleum Co., Ltd.	Do. . .	P. L. .	3,424	19th February 1914.	Do.
Do. . .	(133) Mr. A. D'ortez .	All minerals (except oil).	P. L. .	3,200	30th June 1914.	Do.

P. L.=*Prospecting License.* M. L.=*Mining Lease.*

BURMA—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Southern Shan States.	(134) Mr. R. E. Smith .	Wolfram and other minerals (except mineral oil).	P. L. .	3,040	15th June 1914.	1 year.
Do. . .	(135) Mr. A. C. Martin .	Wolfram, tin and other minerals (except mineral oil).	P. L.	3,200	15th May 1914	Do.
Do. . .	(136) Ko Law Pan .	All minerals (except oil).	P. L. .	360	21st August 1914.	Do.
Do. . .	(137) Do. .	Do. .	P. L.	1,600	4th September 1914.	Do.
Do. . .	(138) Mr. L. Borm .	Antimony and allied minerals.	P. L. .	640	20th August 1914.	Do.
Do. . .	(139) Mr. John Terndrup	Wolfram, tungsten, gold, galena, copper and tin.	P. L. . (renewal).	3,200	30th June 1914.	Do.
Do. . .	(140) Do. . .	Do. .	P. L. . (renewal).	2,720	15th July 1914.	Do.
Tavoy . .	(141) E. Ahmed . .	All minerals (except oil).	P. L. .	3,078·20	20th January 1914.	Do.
Do. . .	(142) Mr. S. Crawshaw .	Do. .	P. L. .	3,100	14th February 1914.	Do.
Do. . .	(143) En Shwe Swe .	Do. .	P. L. .	1,957·84	19th March 1914.	Do.
Do. . .	(144) Maung Lu Pe .	Do. .	P. L. .	790	18th February 1914.	Do.
Do. . .	(145) Mr. S. Crawshaw .	Do. .	P. L. .	3,067	14th February 1914.	Do.
Do. . .	(146) Ma Thaw . .	Do. .	P. L. .	430	4th February 1914.	Do.
Do. . .	(147) Mr. G. E. Elburn .	Do .	P. L. .	910	20th February 1914.	6 months.
Do. . .	(148) Maung Ni . .	Do. .	P. L. .	3,123	2nd March 1914.	1 year.
Do. . .	(149) Leibaoak Syndicate	Do. .	P. L. .	3,135	28th February 1914.	Do.
Do. . .	(150) Lim Kywe Yan .	Do. .	P. L. .	1,700	4th March 1914.	Do.
Do. . .	(151) Kyong Nga . .	Do. .	P. L. . (renewal).	2,816	27th May 1913	Do.
Do. . .	(152) Khoo Tun Byan .	Do. .	P. L. . (renewal).	2,313	19th August 1913.	Do.
Do. . .	(153) Egani (Tavoy) Mining Co., Ltd.	Do. .	P. L. . (renewal).	2,430	1st December 1913.	6 months.
Do. . .	(154) Teong Shwe Sin .	Do. .	P. L. . (renewal).	1,132	8th December 1913.	3 months.

P. L.=*Prospecting License.* M. L.=*Mining Lease.*

BURMA—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Tavoy . .	(155) Ong Hoe Kyin .	All minerals (except oil).	P. L. . (renewal).	822	23rd December 1913.	1 year.
Do. . .	(156) Messrs. The Tenasserim Concessions Ltd.	Do. .	P. L. . (renewal).	1,011·2	3rd January 1914.	Do.
Do. . .	(157) Messrs The Hermingyi Mining Co., Ltd.	Do. .	P. L. . (renewal).	2,099	23rd December 1913.	Do.
Do. . .	(158) Messrs The Rangoon Mining Co., Ltd.	Do. .	P. L. . (renewal).	3,200	24th December 1913.	3 months
Do. . .	(159) Messrs. The Burma Malaya Mines Ltd.	Do . .	P. L. . (renewal).	2,400	29th December 1913.	1 year.
Do. . .	(160) Mr. F G Fitzherbert.	Do. .	P. L. . (renewal).	320	31st October 1913.	Do.
Do. . .	(161) Mr. S Crawshaw .	Do. .	P. L. . (renewal).	620	3rd January 1913.	Y. M. D. 1 9 21
Do. . .	(162) Messrs The Rangoon Mining Co., Ltd.	Do. .	P. L. . (renewal).	3,200	24th March 1914.	6 months.
Do. . .	(163) Ma Thaw . .	Do. .	P. L. (renewal).	850	19th November 1913.	9 months.
Do. . .	(164) Mr. G. E. Ellarn .	Do. .	P. L. . (renewal).	3,100	28th April 1914.	1 year.
Do. . .	(165) Lim Shain . .	Do. .	P. L. .	1,000	2nd September 1914	Do.
Do. . .	(166) Mr F. G. Fitzherbert	Do. .	P. L. .	1,000	17th August 1914.	Do.
Do. . .	(167) C Soo Don . .	Do	P L. .	583	8th September 1914.	Do.
Do. . .	(168) Messrs. Radcliff & Co., Ltd.	Do. .	P. L. .	390·5	22nd July 1914	Do.
Do. . .	(169) Messrs The Burma Malaya Mines Ltd.	Do. .	P. L. .	1,544	19th August 1914.	Do.
Do. . .	(170) Messrs. Crawshaw and Quah Cheng Guan.	Do. .	P. L. . (renewal).	955	22nd March 1914.	Do.
Do. . .	(171) G. R. Gilfillan .	Gold and tin .	P. L. . (renewal)	2,172·52	25th November 1913	Do.
Do. . .	(172) Messrs. Pa Thaung Bros & Co	All minerals (except oil).	P. L. . (renewal).	274	22nd January 1914.	Do.
Do. . .	(173) Messrs The Burma Malaya Mines Ltd.	Do .	P. L. . (renewal).	2,710	13th January 1914.	Do.
Do. . .	(174) Ko Maung Gyi .	Do. .	P. L. . (renewal).	455	19th February 1914.	Do.
Do. . .	(175) Maung E. Zin .	Do. .	P. L. . (renewal).	1,000	22nd July 1914.	Do.

P. L.=*Prospecting License.* M. L.=*Mining Lease.*

BURMA—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Tavoy . .	(176) Messrs. The Egani (Tavoy) Mining Co., Ltd.	All minerals (except oil).	P. L. . (renewal).	2,560	22nd July 1914.	6 months.
Do. . .	(177) Messrs. The Tenasserim Concessions Ltd.	Do. .	P. L. . (renewal).	640	19th June 1914.	1 year.
Do. . .	(178) Messrs. M A. Hangan and H. P. G. Selvey.	Do. .	P. L. .	737	12th November 1914.	3 months.
Do. . .	(179) San Saing Tin .	Do. .	P. L. .	2,100	20th October 1914.	1 year.
Do. . .	(180) Messrs. A. C. Martin and C. H. dePaulsen.	Do. .	P. L. .	766	5th December 1914.	Do.
Do. . .	(181) Maung Ni Toe .	Do. .	P. L. .	1,375	22nd December 1914.	Do.
Do. . .	(182) Maung Lu Pe .	Do. .	P. L. .	780	4th December 1914.	Do.
Do. . .	(183) Mr. G. E. Elburn .	Do. .	P. L. .	9	20th November 1914.	Do.
Do. . .	(184) Tan Chong Yean .	Do. .	P. L. . (renewal).	275	9th November 1914.	Do.
Do. . .	(185) Mr. W. H. Edwards of Messrs. Watkins & Co., Calcutta, the Trustees for Messrs. Turnbulls Ltd. (Glasgow) and the Leibaoak Syndicate.	Do. .	P. L. . (renewal).	2,409	22nd May 1914	Do.
Do. . .	(186) Moolla Gollam Mohamed.	Do. .	P. L. . (renewal).	2,320	23rd June 1914.	Do.
Do. . .	(187) Mr. G. E. Elburn .	Do. .	P. L. . (renewal).	910	19th August 1914.	6 months.
Do. . .	(188) Messrs. Ung Kyi Pe Bros. & Co.	Do. .	P. L. . (renewal).	279	15th September 1914.	1 year.
Do. . .	(189) Ung Hoe Kyin . .	Do. .	P. L. . (renewal).	258	5th November 1914.	Do.
Thatôn . .	(190) M. Ah Khee .	Do. .	P. L. .	20·66	2nd January 1914.	Do.
Do. . .	(191) Maung Sein Swe .	Do. .	P. L. .	3,840	2nd November 1913.	Do.
Do. . .	(192) Maung Po Tha .	Do. .	P. L. .	3,008	12th October 1914.	Do.
Thayetmyo .	(193) Ellahi Buksh .	Mineral oil . .	P. L. .	1,280	20th December 1913	Do.
Do. .	(194) Mr. J. A. Murray .	Do. . .	P. L. . (renewal).	3,840	26th November 1913.	Do.
Do. .	(195) Messrs. The Burma Oil Co., Ltd.	Petroleum . .	P. L. . (renewal).	1,920	26th April 1914.	Do.

P. L.= *Prospecting License.* M. L.= *Mining Lease.*

BURMA—*concld.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Thayetmyo .	(196) Messrs. The British-Burma Petroleum Co., Ltd.	Petroleum . .	P. L. . (renewal).	94·72	22nd May 1914.	1 year.
Do. .	(197) Abu Bucker .	Do. . .	P. L. .	1,920	24th June 1914.	Do.
Do .	(198) Ismail Aboo Ahmed.	Do . .	P. L. .	1,920	9th June 1914.	Do.
Do. .	(199) Messrs The Burma Oil Co., Ltd.	Do. . .	P. L. .	640	Do. .	Do.
Do. .	(200) Do. .	Do. . .	P. L. .	1,440	28th August 1914.	Do.
Do. .	(201) Maung Tun . .	Do. . .	P. L. . (renewal).	222.80	13th December 1913.	Do.
Do. .	(202) Messrs The Burma Oil Co., Ltd.	Do. . .	P. L. . (renewal).	960	6th June 1914	Do.
Do. .	(203) Do. .	Mineral oil . .	P. L. .	3,840	24th September 1914.	Do.
Upper Chindwin	(204) Messrs The Indo-Burma Petroleum Co., Ltd.	Do. . .	P. L. . (renewal).	11,520	12th September 1913.	Do.
Do. .	(205) Do. .	Do. . .	P. L. . (renewal).	12,800	Do. .	Do.
Do. .	(206) Do. .	Do. . .	P. L. . (renewal).	12,800	12th September 1914.	Do.
Do. .	(207) Do. .	Do. . .	P. L. . (renewal).	11,520	Do. .	Do.
Do. .	(208) Do. .	Do. . .	P. L. . (renewal).	3,200	1st October 1914.	Do.
Do. .	(209) Do. .	Do. . .	P. L. . (renewal).	3,200	Do. .	Do.

CENTRAL PROVINCES.

Balaghat .	(210) Babu Kripa Shanker.	Manganese . .	P. L. .	54	17th June 1914.	1 year.
Do. . .	(211) Seth Ramchandra	Do . .	P. L. .	62	18th May 1914	Do.
Do. . .	(212) Do. .	Do. . .	P. L. .	91	Do. .	Do.
Do. . .	(213) Messrs Lalbehari Narayandas and Ramcharan Shankerlal.	Do. . .	M. L. .	25	24th June 1914.	30 years.
Do. . .	(214) Mr. Byramji Pestonji.	Do. . .	M. L. .	25	7th August 1914.	Do.
Do. . .	(215) Babu Kripa Shanker.	Do. . .	P. L. .	126	14th September 1914.	1 year.

P. L.=*Prospecting License.* M. L.=*Mining Lease.*

CENTRAL PROVINCES—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant	Area in acres.	Date of commencement.	Term.
Balaghat . .	(216) Central India Mining Co., Ltd.	Manganese . .	P. L. .	156	14th September 1914.	1 year.
Do. . .	(217) Mr. P. C. Dutt .	Bauxite . .	P. L. .	8,978	Do. .	Do.
Do. . .	(218) Messrs. Lalbehari Narayandas and Ramcharan Shankerlal.	Manganese . .	M. L. .	42	30th June 1914.	5 years.
Do. . .	(219) Indian Manganese Co., Ltd	Do. . .	P. L. .	54	31st October 1914.	1 year.
Betul . .	(220) Rao Bahadur D. R. Shrikhande and Mr. L. L. Rai.	Mica . . .	P. L. .	88	11th May 1914	Do.
Do. . .	(221) Shaikh Shahabuddin	Do. . .	P. L. .	71	17th October 1914	Do.
Do. . .	(222) Do. . .	Copper . .	P. L. .	117	9th November 1914.	Do.
Bhandara . .	(223) Mr. Byramjee Pestonji.	Manganese . .	M. L. .	18	14th October 1913.	Will expire with the original lease, dated the 12th April 1913, to which it is supplementary.
Do. . .	(224) Do. . .	Do. . .	P. L. . (renewal).	13	13th December 1913.	1 year.
Do. . .	(225) Seth Gowardhandas.	Do. . .	P. L. . (renewal).	97	12th March 1914.	6 months.
Do. . .	(226) Sir Kasturchand Daga, K.C.I.E.	Do. . .	P. L. .	85	22nd April 1914.	1 year.
Do. . .	(227) Seth Gowardhandas.	Do. . .	P. L. .	96	Do. .	Do.
Do. . .	(228) Do. .	Do. . .	P. L. .	47	Do. .	Do.
Do. . .	(229) Mr. T. D. Ramchandra Naidu.	Do. . .	P. L. .	122	24th April 1914.	Do.
Do. . .	(230) Nagpur Manganese Mining Syndicate.	Do. . .	P. L. .	462	6th June 1914.	Do.
Do. . .	(231) Messrs. Lal Behari Narayan Das and Ramcharan Shanker Lal.	Do. . .	P. L. .	67	29th June 1914.	Do
Do. . .	(232) Seth Gowardhandas.	Do. . .	M. L. .	54	29th May 1914.	30 years.
Do. . .	(233) Mr. Byramji Pestonji.	Do. . .	M. L. .	75	26th June 1914.	5 years.
Do. . .	(234) Seth Gowardhandas.	Do. . .	P. L. .	270	2nd July 1914	1 year.

P. L.=*Prospecting License.* M. L.=*Mining Lease.*

CENTRAL PROVINCES—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Bhandara	(235) Seth Mahadeo	Manganese	P. L.	200	3rd August 1914.	1 year.
Do.	(236) Do.	Do.	P. L.	47	Do.	Do.
Do.	(237) Rai Sahib D. Lakshminarayan.	Do.	P. L.	65	13th August 1914.	Do.
Do.	(238) Mr. Byramji Pestonji.	Do.	P. L.	10	4th September 1914.	Do.
Do.	(239) Seth Gowardhandas	Do.	P. L.	68	25th September 1914.	Do.
Do.	(240) Seth Mahadeo	Do	P. L.	22	8th August 1914.	Do.
Do.	(241) Central India Mining Co., Ltd.	Do.	P. L. (renewal).	19	28th August 1914.	2 years.
Do.	(242) Nagpur Manganese Mining Syndicate.	Do.	P. L.	33	23rd October 1914.	1 year.
Do.	(243) Messrs. Lalbehari Narayandas and Ramcharan Shankarlal.	Do.	P. L.	2	4th December 1914.	Do.
Do.	(244) Seth Mahadeo	Do.	P. L.	602	18th November 1914.	Do.
Do.	(245) Seth Gowardhandas.	Do.	P. L.	97	16th November 1914	Do.
Bilaspur	(246) Mr. W. J. Considine	Coal and Iron	P. L. (renewal).	11,623	26th March 1914.	Do.
Chanda	(247) Mr. H. Verma and Munshi Kanhaiya Lal.	Coal	P. L.	7,064	20th June 1914.	Do.
Do.	(248) Mulla Hasan Ali Nathubhoy.	Do.	P. L.	4,095	2nd June 1914	Do.
Do.	(249) Mr. Musthyalu Venkat Krishnaih.	Copper	P. L.	982	16th December 1914.	Do.
Chhindwara	(250) Mr. M. B. Dadabhoy, C.I.E.	Manganese.	P. L. (renewal).	58	27th December 1913.	2 months.
Do.	(251) Do.	Do.	P. L. (renewal).	159	29th January 1914.	Do.
Do.	(252) Mr. H. Verma and Munshi Kanhaiya Lal.	Coal	P. L.	1,048	1st June 1914	1 year.
Do.	(253) Do.	Do.	P. L.	5,495	23rd July 1914.	Do.
Do.	(254) Do.	Do.	M. L.	376	26th August 1914.	30 years.
Do.	(255) Messrs. H. V. Low & Co.	Do.	M. L.	270	16th July 1914.	Do.

P. L.=*Prospecting License.* M. L.=*Mining Lease.*

CENTRAL PROVINCES—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Chhindwara .	(256) Indian Manganese Co., Ltd.	Manganese . .	M. L. .	4	18th November 1914.	Will expire with the original lease, dated the 6th February 1904, to which it is supplementary.
Do. . .	(257) Messrs. Shaw Wallace & Co.	Coal . .	P. L. .	1,193	1st October 1914.	1 year
Do. . .	(258) Mr. H. Verma and Munshi Kanhaiya Lal.	Manganese . .	P. L. (renewal).	164	13th September 1914.	Up to 30th June 1915.
Do. . .	(259) Do. . .	Coal . .	P. L. .	618	22nd October 1914.	1 year.
Do. . .	(260) Hon'ble Sir Kasturchand Daga, K.C.I.E.	Manganese . .	P. L. .	142	10th October 1914	Do.
Jubbulpore .	(261) Mr. S. P. Dutt .	Manganese, mica, bauxite, barytes and copper.	P. L. .	565	17th May 1914	Do.
Do. . .	(262) Mr. P. C. Dutt .	Bauxite . .	P. L. .	67	3rd May 1914	Do.
Do. . .	(263) Mr. George Forester.	Iron . .	M. L.	9	10th September 1914.	21 years.
Do. . .	(264) Mr. P. C. Dutt .	Bauxite . .	P. L. (renewal).	1,352	20th August 1914.	1 year.
Do. . .	(265) Do. . .	Iron and Bauxite.	P. L. .	281	22nd October 1914.	Do.
Do. . .	(266) Do. . .	Bauxite . .	P. L. .	558	9th October 1914	Do.
Do. . .	(267) Do. . .	Do. . .	P. L. .	1,006	Do. .	Do.
Do. . .	(268) Katni Cement and Industrial Co., Ltd.	Soapstone, steatite and Talc.	P. L. .	142	14th October 1914.	Do.
Nagpur . .	(269) Nagpur Manganese Mining Syndicate.	Manganese . .	P. L. (renewal).	71	4th November 1913.	Do.
Do. . .	(270) Do. . .	Do. . .	P. L. (renewal).	114	31st December 1913.	Do.
Do. . .	(271) Do. . .	Do. . .	P. L. (renewal).	30	9th February 1914.	Do.
Do. . .	(272) Do. . .	Do. . .	P. L. .	127	31st March 1914.	Do.
Do. . .	(273) Mr. H. Verma and Munshi Kanhaiya Lal.	Do. . .	P. L. .	200	12th June 1914.	Do.
Do. . .	(274) Messrs. Balibhadra Mohanlal.	Do. . .	P. L. .	81	22nd April 1914.	Do.

P. L. = *Prospecting License.* M. L. = *Mining Lease.*

CENTRAL PROVINCES—*contd.*

District.	Grantee	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Nagpur . .	(275) Nagpur Manganese Mining Syndicate.	Manganese . .	P. L. .	16	27th April 1914.	1 year.
Do. .	(276) Do. . .	Do. . .	P. L. .	66	Do. .	Do.
Do. . .	(277) Do. . .	Do. . .	P. L. .	84	3rd June 1914.	Do.
Do. . .	(278) Indian Manganese Co., Ltd.	Do. . .	M. L. .	6	8th April 1914.	Will expire with the original lease, dated the 6th February 1904, to which it is supplementary.
Do. . .	(279) Mr. P. Balkrishna Naidu.	Do. . .	P. L. .	103	9th May 1914	1 year.
Do. . .	(280) Mr. Lakshman Damodar Lele.	Do. . .	P. L. .	144	20th June 1914.	Do.
Do. . .	(281) Do. . .	Do. . .	P. L. .	130	1st May 1914	Do.
Do. . .	(282) Do. . .	Do. . .	P. L. .	17	20th June 1914.	Do.
Do. . .	(283) Messrs. Ganeshram Sheopratab & Sons.	Do. . .	P. L. .	111	Do. .	Do.
Do. . .	(284) Messrs. Goredutt Ganesh Lal and M. D'Costa.	Do. . .	P. L. .	26	3rd June 1914	Do.
Do. . .	(285) Indian Manganese Co., Ltd.	Do . .	P. L. .	231	30th August 1914.	Do.
Do. . .	(286) Messrs. Balibhadra Mohanlal.	Do. . .	P. L. .	35	24th July 1914.	Do.
Do. . .	(287) Messrs. Lalbehari Narayandas and Ramcharan Shankarlal.	Do. . .	M. L. .	212	30th June 1914.	3 years.
Do. . .	(288) Do. . .	Do. . .	M. L. .	38	24th June 1914.	10 years.
Do.	(289) Do. . .	Do. . .	M. L. .	224	25th September 1914.	Do.
Do.	(290) Nagpur Manganese Mining Syndicate.	Do. . .	P. L. .	17	10th August 1914.	1 year.
Do. . .	(291) Do. . .	Do. . .	M. L. .	41	8th August 1914.	5 years.
Do. . .	(292 Do. . .	Do. . .	M. L. .	86	8th August 1914.	Do.
Do. . .	(293) Do. . .	Do. . .	P. L. .	129	10th August 1914.	1 year.

P. L.=*Prospecting License.* M. L.=*Mining Lease.*

CENTRAL PROVINCES—*concld.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Nagpur . .	(294) Mr. Byramji Pestonji.	Coal . .	P. L. .	387	10th August 1914.	1 year.
Do. . .	(295) Babu Madhulal Dugar.	Manganese . .	P. L. .	72	Do. .	Do.
Do. . .	(296) Seth Ramcharan .	Do. . .	P. L. .	227	5th August 1914.	Do.
Do. . .	(297) Do. . .	Do. . .	P. L. . (renewal).	31	23rd August 1914.	Do.
Do. . .	(298) Mr. Hariram Sitaram Patel.	Do. . .	P. L. .	265	24th July 1914.	Do.
Do. . .	(299) Mr. T. B. Kantharia	Do. . .	P. L. .	16	20th July 1914.	Do.
Do. . .	(300) Mr. Lakshman Damodar Lele.	Do. . .	P. L. .	145	7th October 1914.	Do.
Do . .	(301) Messrs. Goredutt Ganesh Lal and M. D'Costa.	Do. . .	P. L. .	96	13th November 1914.	Do.
Do. . .	(302) Mr. Lakshman Damodar Lele.	Do. . .	P. L. .	83	7th October 1914.	Do.
Do. . .	(303) Mr. Ramkrishna Puri Gosai.	Do. . .	P. L. .	503	5th November 1914.	Do.
Do. . .	(304) Babu Madhu Lal Dugar.	Do. . .	P. L. .	177	12th December 1914.	Do.
Do. . .	(305) Mr. Ramkrishna Puri Gosai.	Galena . .	P. L. .	33	14th October 1914.	Do.
Do. . .	(306) Do. . .	Do. .	P. L. .	18	Do. .	Do.
Do. . .	(307) Do. . .	Do. . .	P. L. .	125	Do. .	Do.
Do. . .	(308) Mr. Lakshman Damodar Lele.	Manganese . .	P. L. . (renewal).	105	23rd August 1914.	4 months and 9 days.
Nimar . .	(309) Rao Bahadur Rajaram Sitaram Dikshit.	Lead, copper and silver.	P. L. .	358	12th October 1914.	1 year.
Yeotmal . .	(310) Mr. M. B. Dadabhoy, C.I.E.	Coal . .	M. L. .	1,247	14th October 1914.	30 years.

MADRAS.

Bellary . .	(311) A. Ghose, Esq. .	Manganese . .	M. L. .	1,609·30	2nd February 1914.	30 years.
Guntur . .	(312) Do. . .	Iron ores . .	P. L. .	503·98	6th April 1914	1 year.
Kurnool .	(313) W. A. Beardsell, Esq.	Barytes . .	M. L. .	5·00	16th December 1913.	30 years.
Do. . .	(314) A. Ghose, Esq. .	Diamond . .	M. L. .	22·67	5th April 1914	Do.

P. L. = *Prospecting License.* M. L. = *Mining Lease.*

MADRAS—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Nellore . .	(315) M. R. Ry. Barla Venkata Subba Reddi.	Mica . .	M. L. .	40·50	2nd November 1913.	30 years.
Do. . .	(316) Fred. Cross, Esq. .	Do. . .	P. L. .	51·93	19th July 1913.	1 year.
Do. . .	(317) M. R. Ry. K. Penchalu Reddi.	Do. . .	P. L. .	17·76	29th July 1913.	Do.
Do. . .	(318) Messrs. Hajee Muhammad Badsha Sahib & Co.	Do. .	M. L. .	66·10	10th August 1913.	30 years.
Do. . .	(319) M. R. Ry. P Krishnaswami Mudaliyar.	Do. . .	M. L. .	68·31	10th December 1913.	Do.
Do. . .	(320) M. R. Ry. K. Sesha Reddi.	Do. . .	P. L. .	13·80	19th July 1913.	1 year.
Do. . .	(321) Muhammad Zia-uddin Ahmad Sahib Ansari.	Do. . .	P. L. .	12·30	26th October 1913.	Do.
Do. . .	(322) M. R. Ry. T. Chinkondapa Nayudu.	Do. . .	P. L. .	28·30	21st October 1913.	Do.
Do. . .	(323) H. A. Brandt, Esq.	Do. . .	P. L. .	83·40	Do. .	Do.
Do. . .	(324) M. R. Ry. Y. Gnanamuttu Nadar.	Do. . .	M. L. (patta land)	6·72	16th August 1913.	20 years.
Do. . .	(325) Haji Muhammad Hanif Sahib.	Do. . .	P. L. .	19 74	1st October 1913.	1 year.
Do. . .	(326) M R. Ry. M. Subba Nayudu.	Do. . .	M. L. (patta land).	89	26th October 1913.	Do.
Do. . .	(327) M. R. Ry. Chenchu Krishnamma.	Do. . .	M. L. (patta land)	63·22	16th December 1913.	20 years.
Do. . .	(328) M. R. Ry. K. Ramachandrayya.	Do. . .	P. L. .	10·84	31st August 1913.	1 year.
Do. . .	(329) Do. . .	Do. . .	P. L. .	17·95	Do. .	Do.
Do. . .	(330) Muhammad Gulam Ali Gulam Husain.	Do. . .	P. L. .	89·88	22nd January 1914.	Do.
Do. . .	(331) Shaikh Muhammad Ismail Sahib.	Do. . .	M. L. (patta land).	5 31	22nd November 1913.	20 years.
Do. . .	(332) G. Chenchu Subba Reddi.	Do. . .	P. L. .	17·17	17th January 1914.	1 year.
Do. .	(333) R. C. Dyrnanda Mudaliyar.	Do. . .	P. L. .	11·36	21st January 1914.	Do.
Do. . .	(334) P. Venkatanarappa Reddi.	Do. . .	P. L. .	75·76	1st April 1914	Do.
Do. . .	(335) Ghulam Ali Ghulam Husain.	Do. . .	M. L. .	89·88	Do. .	30 years.
Do. . .	(336) Sankara Mining Syndicate.	Do. . .	M. L. . (patta land).	2·14	10th March 1914.	20 years.

P. L.=*Prospecting License.* M. L.=*Mining Lease.*

MADRAS—*contd.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Nellore . .	(337) Sankara Mining Syndicate.	Mica . .	M. L. . (patta land).	19·95	19th March 1914.	20 years.
Do. . .	(338) K. Rangayya Chetti.	Do. . .	M. L. . (patta land).	3·12	9th April 1914	Do.
Do. . .	(339) H. A. Brandt, Esq.	Do. . .	P. L. .	52·93	29th January 1914.	1 year.
Do. . .	(340) Mosa Abdul Rahiman Saheb.	Do. . .	M. L. . (patta land).	4·72	1st April 1914	20 years.
Do. . .	(341) M. R. Ry. G. Subramaniam.	Do. . .	P. L. .	17·70	Do. .	1 year.
Do. . .	(342) Do. . .	Do. . .	M. L. .	132·52	Do. .	30 years.
Do. . .	(343) Khan Bahadur Muhammad Safdar Hussain Khan Sahib.	Do. . .	M. L. .	224·73	Do. .	Do.
Do. . .	(344) The Sankara Mining Syndicate.	Do. . .	M. L. .	65·04	Do. .	Do.
Do. . .	(345) M. R. Ry. P. V. Krishna Rao.	Do. . .	M. L.	13·25	Do. .	Do.
Do. . .	(346) M. R. Ry. P. Krishnaswami Mudaliyar.	Do. . .	M. L. .	64·80	1st October 1914.	Do.
Do. . .	(347) M. R. Ry. P. Venkatanarapa Reddi.	Do. . .	M. L. .	103·22	1st August 1914.	Do.
Do. . .	(348) M. R. Ry. P. Krishnasawmy Mudaliyar.	Do. . .	M. L. .	93·31	1st January 1915.	Do.
Do. . .	(349) M. R. Ry. K. Venkataramanayya.	Do. . .	M. L. .	24·79	1st November ber 1914.	Do.
Do. . .	(350) M. R. Ry. P. Venkatarama Nayudu.	Do. . .	M. L. .	103 94	Do. .	Do.
Do. . .	(351) Messrs. Hajee Muhammad Badsha Sahib & Co.	Do. . .	M L. .	26·40	1st August 1914.	Do.
Do. . .	(352) M. R. Ry. P. Venkatarama Nayudu.	Do. . .	P. L. .	1 75	8th September 1914.	1 year.
Do. . .	(353) M. R. Ry. P. Kannappa Nayudu.	Do. . .	P. L. .	.9 97	23rd September 1914.	Do.
Do. . .	(354) Raja Vasi Reddi Sri Chandramouleswara Prasad Bahadur.	Do . .	P. L. .	8 61	19th October 1914.	Do.
Do. . .	(355) Messrs. A. M. Jeevanjee & Co.	Do. . .	P. L. .	39 02	22nd December 1914.	Do.
South Canara .	(356) Mr. Timothy Pinto	Corundum . .	P. L. .	292·61	1st August 1914.	Do.
Tinnevelly .	(357) Sri Krishna Doss of Bikaner of Rajputana.	Garnet . .	P. L. .	21·25	January 1914	Do.

P. L. = *Prospecting License.* M. L. = *Mining Lease.*

MADRAS—*concld.*

DISTRICT.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Tinnevelly .	(358) Annavi *alias* Ayyappa Nadar of Karaikoil.	Garnet . .	P. L. .	6·27	10th March 1914.	1 year.
Do. . .	(359) A. Sankarakumara Chettiyar of Kotar, Nagarkoil.	Do. . .	M. L. (patta land).	·15	15th August 1914.	Do.
Do. . .	(360) S. Samuel Nadar of Karaikoil, Nangumeri taluk.	Do. . .	M. L. (patta land).	3·11	23rd June 1914.	Do.
Do. . .	(361) T. Ramaswami Nadar of Karaikoil.	Do. . .	M. L. (patta land).	2·00	3rd September 1914.	Do.

PUNJAB.

Attock . .	(362) The Attock Oil Co., Ltd., through Messrs. Steel Bros. & Co., Rangoon.	Petroleum . .	P. L. .	5,760	14th September 1914.	1 year.
Do. . .	(363) Do. . .	Do. . .	P. L. .	3,840	Do. .	Do.

P. L.=*Prospecting License.* M. L.=*Mining Lease.*

SUMMARY.

PROVINCES.	Prospecting Licenses.	Mining Leases.	Total of each Province.
Assam	5	..	5
Baluchistan	1	6	7
Bihar and Orissa	10	4	14
Bombay	1	..	1
Burma	179	3	182
Central Provinces	84	17	101
Madras	23	28	51
Punjab	2	..	2
Totals for each kind and Grand Total, 1914 . .	305	58	363

	Prospecting Licenses.	Exploring Licenses.	Mining Leases.	Total.
TOTAL FOR 1913 .	383	53	59	495

CLASSIFICATION OF LICENSES AND LEASES.

TABLE 31.—*Prospecting Licenses granted in Assam during 1914.*

DISTRICT.	1914.		
	No.	Area in acres.	Mineral.
Khasi and Jaintia Hills . .	1	12,704	Gold and certain other allied minerals.
Do.	1	12,704	Tin and wolfram.
Do. . . .	1	8,160	Gold, tin and certain other allied minerals.
Do. . . .	1	7,040	Mineral oil.
Lakhimpur	1	5,546·6	Oil.
TOTAL .	5	..	

TABLE 32.—*Prospecting Licenses and Mining Leases granted in Baluchistan during 1914.*

DISTRICT.	1914.		
	No.	Area in acres.	Mineral.
Prospecting Licenses.			
Kalat	1	400,640	Oil.
TOTAL .	1	..	
Mining Leases.			
Kalat	1	80	Coal.
Loralai	1	80	Do.
Quetta	2	108·40	Do.
Sibi	1	80	Do.
Zhob	1	80	Chromite.
TOTAL .	6	..	

TABLE 33.—*Prospecting Licenses and Mining Leases granted in Bihar and Orissa during 1914.*

District.	1914. No.	1914. Area in acres.	1914. Minerals.
Prospecting Licenses.			
Hazaribagh	3	573·23	Mica.
Sambalpur	1	1,300	Coal.
Singhbhum	3	2,291·28	Manganese.
Do.	3	5,684·56	Chromite.
TOTAL	10	..	
Mining Leases.			
Hazaribagh	3	196	Mica.
Santhal Parganas	1	2	Coal.
TOTAL	4	..	

TABLE 34.—*Prospecting Licenses granted in Bombay during 1914.*

District.	1914. No.	1914. Area in acres.	1914. Mineral.
Panch Mahals	1	530	Manganese.
TOTAL	1	..	

TABLE 35.—*Prospecting Licenses and Mining Leases granted in Burma during 1914.*

DISTRICT.	1914. No.	1914. Area in acres.	1914. Mineral.
Prospecting Licenses.			
Amherst	3	5,760	All minerals except oil.
Do.	1	960	Gold, silver, tin, copper, wolfram and antimony.
Katha	1	960	Lead and silver.
Lower Chindwin	1	960	Mineral oil.
Do.	1	1,440	All minerals except oil.
Magwe	6	7,103	Mineral oil.
Do.	1	1,520	Petroleum.
Mandalay	1	640	Copper, lead and other minerals (except mineral oil).
Meiktila	1	3,200	Wolfram.
Mergui	37	58,351·95	All minerals except oil.
Do.	1	1,454·08	Gold.
Do.	1	2,362·88	Coal.
Minbu	20	13,939·03	Mineral oil.
Myingyan	2	848·10	Do.
Myitkyina	4	8,460·8	Gold.
Do.	1	4,800	Gold, platinum and minerals of platinum group.
Do.	1	640	Copper, silver and iron.
Do.	1	3,600	Gold and allied minerals.
Northern Shan States	1	640	Lead, silver and allied minerals.
Do.	1	3,200	Gold, silver, lead, iron and zinc.
Do.	1	2,560	Copper, galena and allied minerals.
Do.	1	2,560	Antimony, lead and silver.
Pakokku	12	26,428·36	Mineral oil.
Prome	1	1,862·4	Do.
Shwebo	1	3,424	Do.
Do.	1	3,200	All minerals except oil.
Southern Shan States	1	3,040	Wolfram and other minerals (except mineral oil).
Do.	1	3,200	Wolfram, tin and other minerals (except mineral oil).
Carried over	105	..	

TABLE 35.—*Prospecting Licenses and Mining Leases granted in Burma during 1914*—concld.

DISTRICT.	1914.		
	No.	Area in acres.	Mineral.

Prospecting Licenses—*concld.*

Brought forward .	105	..	
Southern Shan States . .	2	1,960	All minerals except oil.
Do. . . .	1	640	Antimony and allied minerals.
Do. . . .	2	5,920	Wolfram, tungsten, gold, galena, copper and tin.
Tavoy	48	72,963·74	All minerals except oil.
Do.	1	2,172·52	Gold and tin.
Thaton	3	6,868·66	All minerals except oil.
Thayetmyo	3	8,960	Mineral oil.
Do.	8	9,117·52	Petroleum.
Upper Chindwin . . .	6	54,040	Mineral oil.
TOTAL .	179	..	

Mining Leases.

Minbu	1	78·59	Mineral oil.
Pakokku	2	1,098·22	Do.
TOTAL .	3	..	

TABLE 36.—*Prospecting Licenses and Mining Leases granted in the Central Provinces during 1914.*

District.	1914. No.	1914. Area in acres.	1914. Mineral.
Prospecting Licenses.			
Balaghat	6	523	Manganese.
Do.	1	8,978	Bauxite.
Betul	2	162	Mica.
Do.	1	147	Copper.
Bhandara	20	2,424	Manganese.
Bilaspur	1	11,623	Coal and iron.
Chanda	2	11,159	Coal.
Do.	1	982	Copper.
Chhindwara	4	523	Manganese.
Do.	4	8,354	Coal.
Jubbulpore	1	565	Manganese, mica, bauxite, barytes and copper.
Do.	1	281	Iron and bauxite.
Do.	1	142	Soapstone, steatite and talc.
Do.	4	2,983	Bauxite.
Nagpur	30	3,452	Manganese.
Do.	1	387	Coal.
Do.	3	176	Galena.
Nimar	1	358	Lead, copper and silver.
TOTAL	84	..	
Mining Leases.			
Balaghat	3	92	Manganese
Bhandara	3	147	Do.
Chhindwara	2	646	Coal.
Do.	1	4	Manganese.
Jubbulpore	1	9	Iron.
Nagpur	6	607	Manganese.
Yeotmal	1	1,247	Coal
TOTAL	17	..	

TABLE 37.—*Prospecting Licenses and Mining Leases granted in Madras during 1914.*

District.	1914. No.	1914. Area in acres.	1914. Mineral.
Prospecting Licenses.			
Guntur	1	503·98	Iron-ores.
Nellore	19	590·17	Mica.
South Canara	1	292·61	Corundum.
Tinnevelly	2	27·52	Garnet.
TOTAL	23	..	
Mining Leases.			
Bellary	1	1,609·30	Manganese.
Kurnool	1	5·00	Barytes.
Do.	1	22·67	Diamond.
Nellore	22	1,222·86	Mica.
Tinnevelly	3	5·26	Garnet.
TOTAL	28	..	

TABLE 38.—*Prospecting Licenses granted in the Punjab during 1914.*

District.	1914. No.	1914. Area in acres.	1914. Mineral.
Attock	2	9,600	Petroleum.
TOTAL	2	..	

THREE NEW INDIAN METEORITES; KUTTIPPURAM, SHUPIYAN AND KAMSAGAR BY J. COGGIN BROWN, M. SC., F.G.S., *Geological Survey of India.* (With Plates 7-20.)

THE KUTTIPPURAM METEORITE.

ON the 10th and 11th of April 1914, accounts of a meteorite fall appeared in various Indian newspapers. The following extract from the Calcutta "Statesman" is typical of them all. It is dated Calicut, April 10th, 1914: "On last Monday morning (April 6th), a terrible rumbling noise in the sky was heard, and it was generally believed that it was thunder which forecasted the early approach of the south-west monsoon. Reports now received go to show that meteorite stones, weighing about a hundred pounds, had fallen immediately after the noise in Ponnani, Tirur, Trurangadi, Kuttippuram, Ottapatam, and other places in South Malabar, and that they had gone about five or six feet deep into the earth. All the stones, which so fell, are reported to have been broken to pieces, owing to the extraordinary force with which they fell."

All meteorites which fall in British India are the property of the Government of India, and, as such, are added to the great collection in the Geological Museum, Calcutta. The Collector of Malabar, who is in charge of the district in which the stones fell, was requested, therefore, to obtain them, together with any available particulars of the occurrence.

Several Indian meteorites have previously been lost to science owing to the veneration bestowed on such objects by superstitious villagers, who regard the phenomena accompanying their descent as supernatural manifestations, and place the stones themselves in the temples, for public adoration, whence it is quite impossible to obtain them.

The Geological Survey Department is greatly indebted to Mr. C. A. Innes, the Officiating Collector of Malabar, for the trouble he took to secure the stones and for the completeness of the enquiries which he instituted regarding them.

In forwarding eleven fragments Mr. Innes submitted the following report which is reproduced below in his own words:—

"Careful enquiries have been made and it has now been ascertained that meteoric stones fell on the 6th April last only at the following places in the Ponnani taluk of this district: (1) Kuttayi, (2) Triprangod, (3) Trikkanapuram and (4) Kuttippuram. These four places are practically in a straight line and you will find them all clearly marked in the Survey of India Topographical Sheets No. 49-N -13 and 58-B—1. Kuttayi is on the coast; Kuttippuram is 9 or 10 miles inland in a due easterly direction from Kuttayi. At Kuttayi four small stones are reported to have fallen within a distance of one mile. One of these stones is said to have measured $\frac{3}{4}' \times \frac{1}{2}' \times \frac{1}{2}'$, but only one small stone has been secured. One stone has been secured from Triprangod and six from Trikkanapuram. At Kuttippuram one large stone weighing it is said some 71 lbs. fell. It is now in three pieces all of which have been secured.

"I summarize below such information as I have been able to collect. Accounts vary as to the exact time at which the meteorites fell. At Kuttayi 6-30 A.M. is given as the time; at Kuttippuram 7 A.M.; while another account mentions 7-30 A.M.

"At Kuttayi there was a festival at the mosque on the morning of the 6th April, and many people who had collected at the sea shore had a good opportunity of observing the phenomenon. First they heard two loud and almost simultaneous reports which they compared to the noise made by *kadinas*. *Kadinas* are small mortars which are much in favour in Malabar and which are exploded with terrific noise at times of festival. A continuous roaring sound like that caused by a volley of musketry followed and at the same time there was a flash like a flash of lightning. (It is more probable that the flash preceded or accompanied the first two loud reports, but the account above is the one given by the Deputy Tahsildar of Tirur in whose division Kuttayi is.) The direction of the flash was from west to east and the people who saw it said that in appearance it resembled a palm tree. The stones which fell at Kuttayi penetrated only about 6 inches into the earth. They were slightly warm when picked up and there was no smell.

"At Kuttippuram the stone fell in a paddy field, which was then dry, and penetrated some feet into the ground. A cloud of dust rose into the air, and this attracted people to the spot. But they were apparently afraid to touch the stone, and it was not till some hours later that it was dug out and then it was quite cold. The people who gathered at the spot say that for some minutes after the fall there was a smell of backwater mud in the vicinity. Backwater mud or silt is black oozy stuff which is full of rotting organic matter and its smell, which is familiar to everyone who lives in Malabar, is most unpleasant.

"Triprangod is about 3 miles from Kuttayi; Trikkanapuram about 5 miles from Triprangod and Kuttippuram about 2 miles from Trikkanapuram.

"The noise of the first two loud reports is said to have been heard at various places in Malabar. The Tahsildar heard it distinctly at Ponnani which is 4½ miles south of Kuttayi. A gentleman who lives close to my own bungalow at Calicut (30 miles north of Kuttayi), also says he heard the noise; while another enthusiastic gentleman claims (I believe) to have heard it at Cannanore which is 60 miles north of Calicut.

"I am sorry I cannot give you more definite information on the points referred to in your letter, but such information as my officers have been able to get has been gathered from villagers who are not exact observers of physical phenomena."

The following list gives the weights of the fragments and the names of the places in which they were picked up:—

259 A	18,236 gms.	
259 B	10,989 ,,	
259 C	3,374 ,,	
259 D	3,993 ,,	
259 E	738 ,,	
259 F	427 ,,	
259 G	221 ,,	
259 H	206 ,,	
259 I	121 ,,	
259 J	63 ,,	
259 K	60 ,,	
259 L	9 ,,	(Small fragments and dust.)

259 is the number which the meteorite bears in the Geological Survey register of meteoric stones. In the new catalogue its number is 194[1].

[1] The new catalogue of the meteorite collection is now in the press and will shortly be published.

A, B and C, which are parts of the same large stone and easily fit together, fell in Kuttippuram. D, E, F, G, H and I fell in Trikkanapuram, J in Triprangod and K in Kuttayi. The map (Plate 20) shows the exact position of each of these villages, all of which are situated in the Ponnani taluk of the Malabar District in the Madras Presidency Kuttayi is on the coast in Lat. 10° 51′ : Long. 75° 54½′. Triprangod in Lat. 10° 50½′ : Long. 75° 57′, is 3¼ miles further inland in a line 2° south of east. Trikkanapuram is 7½ miles from Kuttayi in a line 9° south of east and is situated in Lat. 10° 49½′ : Long. 76° 1′, while Kuttippuram where the largest stone fell is in Lat. 10° 50½′ : Long. 76° 2′, 8¾ miles from the coast at Kuttayi, in a line 2° south of east.

It would appear therefore that a large meteor, travelling with a low trajectory, approached the Malabar Coast from the Arabian Sea, in a direction a few degrees south of east, and bursting into fragments, scattered portions of itself over the villages mentioned, for the greater momentum of the larger stones would carry them further than the small ones. Confirmatory evidence is supplied by the Deputy Tahsildar of Tirur who reported that the direction of the flash which accompanied the fall was from west to east at Kuttayi. From the small size of the Kuttayi fragments, and the large dimensions of the mass which fell in Kuttippuram, it seems to me that little if any of the material was lost by falling into the sea.

Description of the Kuttippuram Stone.

This large stone is broken into three pieces and part of the front and lateral surfaces are missing. These injuries may have been caused by its impact on reaching the ground, or they may have been inflicted later by inquisitive persons. For this reason it is impossible to describe exactly its original shape, but the larger portions which remain give a very good idea of what that shape was. Standing on the broken area and looked at from the end the meteorite has the appearance shown in Pl. 7. from which it seems to be somewhat prismatic. On the whole it is perhaps best to describe it as a very irregular tetrahedron, with one corner replaced by the flat face seen in Pl. 7, and modified of course by the broken and missing pieces. In this position it measures 28 cms. (11 inches) in height, at the end shown in Pl. 7, which is believed to be the rear face, decreasing to 18 cms. (7 inches) at the front face or "brustseite," which is smashed. Its length is 32 cms.

(12½ .inches), and its greatest breadth in a line approximately perpendicular to this is 31·5 cms. (12⅜ inches). It weighs 32,599 gms. The specific gravity of this large mass has not been taken, but that of the smaller piece 259 II is 3·558. As will be seen later, the various fragments which comprise this fall are of a very uniform composition, and there is no reason to believe that the specific gravity of the large mass differs very much from that of the smaller piece.

The peculiar form of the stone is due partly to fracturing, and partly to the atmospheric erosion to which it has been subjected during its passage through the air. Apart from the fact that the edge which struck the earth first is marked by a thick deposit of hardened, sandy soil, the general shape of the stone, its differences of curvature, the rounding of its edges, the variation in the thickness and structures of its crust and the distribution of the pittings on its surface, all tend to prove that this edge was the front one during the trans-atmospheric existence of the meteorite.

In Pl. 11, this front edge commences at the rounded corner in the lower right half of the photograph where it is covered with the brown, sandy earth already referred to, and continues up to the crack which divides the face into two pieces, and by means of which the portion marked A in the tracing has split off along a slickenside plane. [Plate 11, see tracing, for positions of A and B.] The remainder of the front edge and face has been broken away after the fashion indicated in Pl. 8. After photographs had been taken, part of the adherent earth was removed, and it was found to be not entirely underlain by crust, some of which must have been scaled off at a comparatively late period of the trans-atmospheric flight. Near the corner, the edge flattens into a minor area 3 or 4 cms. across.

The greater part of the stone is covered with crust, the exceptions being the broken end shown in Pl. 8, the missing portion which comes between A and B in Pl. 11, the medial portion of B in Pl. 11, and the left hand lower corner in the same figure. In addition to these, there are smaller patches where the crust has been removed, usually in the vicinity of the cracks which separate the three pieces.

The edge shown in Pl. 11, and also those made by the rear with the other faces are comparatively sharp, the others are more rounded. The sharp edge of the rear face in Pl. 7, and the flatness of its plane, indicate an early fracture along this surface.

The greater portion of the crust is corrugated with deep pits or piezoglyphs, furrows and channels, caused by the differential fusion of the upper layers of the stone and not by the combustion of included sulphide nodules. On the rear face they are only faintly traceable and on the top of the stone they are absent. (See the top line in Pls. 8, 9 and 11.) They attain their maximum development on the face illustrated in Pl. 11, though they are also present on the lateral faces seen in Pl. 8, and in the lower part of Pl. 10.

The pits seen in Pl. 11 have a circular, polygonal or irregular outline, and are either broad and shallow, with low rounded edges, sloping gently off into a more or less flattened base, or deeper, with steeper sides, making short sharp ridges between them. They do not possess any definite arrangement, except in the lower portion immediately above the adherent earth, where a long, funnel-shaped depression, with its mouth pointing towards the rear surface, seems to have been produced by the fusion of the ridges of several pits, the remains of which are still visible as low prominences. Elongated depressions of approximately elliptical outline, produced by two confluent pits, are also present. The average diameter of the better-marked pits is about 2 cms. The minute lines of crustal drift in the pits themselves show no particular distribution in the great majority of cases, but occasionally they are seen to radiate from the centre. Below the adherent earth in the lower right hand corner of Pl. 9, there are two long furrows, one much deeper than the other. The larger is 4 cms. in length, 1 cm. in breadth, and over 1 cm. in depth at the centre. In a general way both of them point from the front to the rear of the stone, showing the direction of the air currents by which they were produced.

The pits which are visible on the face seen in the lower left hand portion of Pl. 11, and in the lower right hand part of Pl. 10, are not so well developed as those just described. Instead of the deep pits, broad shallow ones occur, with diameters up to 4 cms. across and circular or elliptical outlines. These are made up of smaller depressions with badly defined edges. The minute irregular network of the crustal drift is more in evidence on this side than on the former one, but it does not exhibit any particular distribution. The crust itself is thicker and has scaled off a slight prominence. All these phenomena point to a diminished air resistance on this face.

The opposite lateral face is seen in Pl. 8. The part which lies in shadow on the upper left hand corner of the print contains several shallow elongated depressions, the long axes of which point towards the rear end. The rest of the upper portion of this face consists of a broad triangular area, next to the shadowed portion just described, a rounded and smoothed surface above this, and a larger space below and to the right, covered with depressions the long axes of which are orientated at right angles to the direction of flight. The lower part, below the crack, is rounded off into the lower section of the rear face and is comparatively smooth. The triangular area contains a deep groove. which has a length of 8 cms., a breadth of 2 cms., and a depth of 2 cms. below the general surrounding level. It possesses a curious short continuation at right angles to it on the left hand, evidently produced by confluence with a deep pit. As the photograph shows, its lower bounding ridge is steep and sharp, but the upper ridge is low and gives place to four shallow pits of polygonal outlines. The central two of these are separated by a ridge from a confluent depression above them. On the upper surface, just visible in the photograph, is a deep triangular pit, while on the extreme left, a circular one with an inner crateriform ring is situated. Above these again, there is a small, but deep, flat-bottomed depression, close to an elongated pit and surrounded by four smaller ones. Although the elongated depressions which occupy the rest of this portion are distinctive and arranged with their long axes pointing in the same direction, they have neither the depth nor the steepness of those on the front face. (Pl. 11.)

The rear face is seen best in Pl. 7. With the exception of a patch on the left, it is crusted. It is crossed by two fractures, which divide it approximately at right angles. Small shallow pittings are found over the greater part of its surface, often merging into one another. They are not uniform in shape or distribution. Large areas on the top and at the upper right hand corner possess a scooped out appearance, and are lined with small depressions of an average width of 1 cm. The crustal drift lines are longer and more thread-like than those of the other faces, but all they show is a radial arrangement, as if they were produced by heaping up from a centre of fusion. Here the crust attains its maximum thickness and its greatest irregularity of surface. The face itself appears to have been originally a fracture plane, and its edges are more or less sharp.

The Crust.

Taken on the whole the crust of the stone is remarkably uniform in thickness and only the slight differences already mentioned have been noticed. It is of a dull black, lustreless colour, with a few small circular or elliptical patches of shining black. These when touched with a file prove to be fused metallic grains. Sometimes they project as small rounded knobs. The general appearance of the crust indicates a nearly felspar-free stone of the olivine-pyroxene type, which it has indeed proved to be on petrological examination. Even to the naked eye, the surface of the crust is roughened, and when examined with a lens the roughness is seen to be caused by minute irregular threads, which form anastomosing systems, or a kind of lattice work pattern, over the outer crust of the entire stone. I term this structure "minutely scoriaceous," because under a lens it has a cindery appearance, which I regard as the result of fusion. Large areas of the crust are of a greyish-black tint, but this is only due to the accumulation of dust particles in the minute slaggy pores. Other parts show a few small scattered rust spots, and a certain amount of brown staining is present, which has been caused by the contact of the crust with the soil.

Internal Appearance and Structure.

The interior of the stone is of a uniformly light greyish-white appearance. Under a lens, white and light grey minerals can be seen, together with small, though well-distributed, metallic grains. In places small globules of a light bronzy troilite occur. The chondritic structure is hardly apparent to the naked eye, yet, very rarely, small spherical chondri do project. Darker grey patches, 3 or 4 mms. long, are also found here and there. The stone is traversed by very delicate black veins. In the large mass, eleven of these are present and at least seven of them are approximately parallel. They greatly resemble thin lines drawn by a hard lead pencil. The stone is a typical veined white chondrite, Cwa.

Perhaps the most interesting peculiarity of this stone is the large slickensided surface along which the piece A, and the missing portion above it, have broken off. (See Pl. 11 and tracing.) Pl. 9 is a photograph of the stone with this part removed, and Pl. 10 a similar representation taken in a side light. This large slickensided surface is approximately square, and has an area of at least 240 sq. cms. It is not an exact plane, as the surface exhibits a little rolling. It must continue down and to the right, but there is no indication on the crust to show where the two meet. The slickensided surface is covered by a shining black, graphitic-looking substance, stained a dull red in places by rust. Its patchy appearance in the photographs is due to fragments sticking to the opposite sides after separation of the pieces. The parallel veins described in an earlier paragraph meet the slickenside plane at an angle of approximately 115°. Lines of weakness of this nature in a stone would naturally cause it to shatter along such a position on receiving a severe impact. It is curious to observe that the plane approximately coincides with what I believe to be the direction of flight.

An attempt was made to polish a surface of the piece numbered 259H, but owing to the friable character of the stone this was found to be practically impossible. On the smoothed surface, light grey chondri with rounded outlines can be seen. They have an average diameter of 1·75 mms., but occasionally reach 3 mms. The groundmass is white and is abundantly sprinkled with small sulphide and metallic grains. Light brown ferruginous stains, although usually found close to most of the metallic points, are more strongly in evidence along a black vein which traverses the specimen. This seems to prove that fine metallic particles are present in the vein.

Composition and Microstructure.

Under the microscope in thin sections, the chondri are not seen so well as they are on the smoothed surface of the stone. The microstructure as a whole is a confused, fine-granular one (see Pl. 15, fig. 1), with few chondri and fragments of chondri, not at all well differentiated from the rest of the groundmass.

Olivine and enstatite, in about equal quantities, are the principal silicates present. A monoclinic pyroxene which simulates the rhombic form, and is only to be distinguished by its inclined though low angle of extinction, occurs in small amounts. There are also a few clear grains which I take to be felspar.

Olivine and enstatite are also the chief minerals in the chondri. The former is found in the familiar monosomatic, polysomatic and ribbed forms. The latter, which is the more abundant of the two as far as the chondri are concerned, builds the usual fan-like radiating structures, which are often broken and imperfect, and also dense nearly crypto-crystalline masses. When these are examined under high powers they are seen to be composed of closely packed mosaics of small irregular particles of enstatite, with an occasional olivine granule. This structure is not like that of minerals crystalizing from a molten magma. Though not exactly analagous, similar structures have been observed by Merrill in the Hendersonville meteorite, though in this case the fragments are imbedded in a cement. Merrill is of opinion that the structure in the case of the American fall, is suggestive of a partial recrystallization of fine detrital material as seen in sundry metamorphic schists.[1]

Sometimes the radiated enstatite chondri are edged with small opaque grains of nickel-iron, troilite and specks of a black graphitic substance. One small olivine chondrus has a circular border of this mineral and a band of it down the centre, the two segments being filled in with minute olivine and enstatite grains. It also includes a few grains of metal and sulphide. Another unusual chondrule has rod-like olivine crystals set in an opaque black background, with a ragged irregular edge partly in contact with the granular olivine and enstatite of the groundmass and partly separated from it by a discontinuous zone of clear felspar grains. A similar form of polygonal outline is almost completely surrounded by a zone of water-clear felspar grains, the centre being opaque for the greater part, though speckled in places with minute transparent points. Intergrowths of olivine and enstatite also occur in the chondri. In one case two series of long rods of the former mineral meet at a wide angle with interpenetrating ends, and the spaces between them occupied by enstatite. The outlines of the chondri occasionally seem to indicate compression as they are flattened and not perfectly circular. The diameter of the best developed ones is approximately 1 mm., a few are larger, the great majority are smaller than this.

A microscope study of the groundmass in section revealed an exceedingly confused aggregate of olivine and enstatite grains and

[1] G. P. Merrill: Notes on the Composition and Structure of the Hendersonville, North Carolina, meteorite. *Proc., U. S. Nat. Mus.*, Vol. XXXII, pp. 79—82.

particles, interspersed with metallic nickel-iron, sulphide, and a few specks of a black, graphitic mineral. Occasionally there is a small, monoclinic pyroxene grain and a little felspar in small granules which exhibit bright grey polarization colours. The olivine grains are the largest, and although a few tend to show crystal outlines, the majority possess very irregular boundaries. Both the olivine and enstatite grains are much broken and fissured, though they are remarkably clear and free from clouding and inclusions. The larger grains are set in a finer matrix, which under high powers is resolved into the same minerals with the same confused arrangement. No true glass was observed. The enstatite of the groundmass sometimes builds flat tabular forms but is generally present as anhedral grains, rarely showing a few opaque inclusions.

The Opaque Minerals and Veins.

The opaque minerals are bright metallic nickel-iron, a light bronze sulphide and a black graphitic substance. They occur in rounded or irregular grains, separated or in juxtaposition, and also form larger irregular shapes. Sometimes the iron and sulphide grains have a kind of broken linear arrangement. The graphitic material has been seen to enclose portions of the fine granular groundmass, and it is evidently related to the substance which fills the fine veins. The latter pierce both groundmass and chondri indiscriminately. Sections cut especially for the study of the veins reveal complicated systems which branch in a most irregular way, enclosing the granular groundmass which does not appear to have suffered any alteration thereby. (See Pl. 15, figs. 3, 4.) The broader veins have a continuous inner lining of the opaque black graphitic mineral and are occasionally filled with sulphide and a little metal.

Petrographical Characters of the Crust.

The crust is usually ·8—·9 mms. thick and easily divisible into three zones. A well-defined outer layer approximately ·05 mms. thick. Inside this there is a clear layer composed of olivine and pyroxene grains, running into and not sharply differentiated from the third and thickest layer, which has a porous slaggy appearance, opaque for the greater part, but pierced with clear particles of the same crystals, olivine and enstatite, in places. In one section which was examined a large olivine crystal extends across the three zones. It is bordered by a black opaque rim on the outside; in the second zone it is practically unaltered; in the third zone a black substance has developed and spread out from the cracks, leaving a network of clear unaltered material. The inner border of the third zone, where it joins the rest of the stone, is well differentiated and no alteration continues beyond it.

Description of 259 D.

This is a big irregular piece broken from a still larger mass. Its general appearance is shown in Pls. 12 and 13. Standing on its flat end it measures 19·5 cms. ($7\frac{3}{4}$ inches) long, 14 cms. ($5\frac{1}{2}$ inches) in maximum breadth, and 9·5 cms. ($3\frac{3}{4}$ inches) in maximum thickness. The flat end shows a few, broad, shallow depressions, some of which have been produced by the confluence of smaller pits. The opposite end is pointed, as the photograph shows, and is marked with shallow confluent pits separated by broad gently sloping ridges, and by a long funnel-shaped depression which is continued right across the stone. Where this meets the face shown in Pl. 13, it is 1 cm. across, but it widens out to over 4 cms. on the opposite side. It is bounded on the left by a sharp ridge, on the top of which there is a thickening of the crust. The opposite ridge is more strongly developed at the lower end only. The drift lines, when they possess any definite direction, cross the funnel. Below it the obtuse end sharply meets the face shown in Pl. 13. This is covered with large and small pits, the broadest and deepest of which on the lower part exhibit radial drift lines. The face meets the flat end in a right angle, the edge being quite sharp. A recent fracture of the stone, crossed by the typical thin black veins which distinguish this meteorite, is shown on the left of Pl. 13. The opposite side, not shown in the photographs, consists of larger and smaller faces running the entire length of the stone. Depressions do occur, but the majority of them are so broad and flattened out as to rather deserve the term undulations. The most interesting feature of this stone is the face shown in Fig. 12. It is a trans-atmospheric fracture over which a thin crust just developed before its impact with the earth. The irregularities of the fracture surface are barely crusted over and there was not sufficient time for a general smoothing down, or for the production of pits. The irregularities are accentuated in the photograph by a light brown earth which adheres to the bottoms of some of them and which was undoubtedly picked up when the stone fell.

The crust.

As a whole the crust is not so dull as that of the larger specimen and it contains more numerous and bigger, brighter patches. The crust on the obtuse end and on the side shown in Pl. 13 has a lustrous black colour and is marked with drift lines, minute scoriations and small projecting blebs of fused metal. The crust of the flat end has developed a series of minute intersecting shrinkage cracks.

The interior.

The general appearance of the interior of the larger stone and this one is so much alike that a separate description is unnecessary. The veins have not the same parallel arrangement, producing rather an irregular network, while one large spherical chondrus, 9 mms. in diameter, projects from the fractured surface.

I have attempted to fit this meteorite, which is so evidently part of a much larger stone, on to the big one but it does not coincide with any of its fractures.

Brief Descriptions of Smaller Specimens.

259 E, is a corner piece partly covered with crust showing pits and depressions with very well-marked, radial, drift lines. Both the crust and interior are very rusted. Veining and slickensiding are present. See Pl. 14, fig. 4.

259 F, which is illustrated in Pl. 14, fig. 1, is partly covered with a smooth, rather shining, black crust. Its interior is not so rusted as that of the previous specimen, while thick and thin black veins and a small patch of slickensiding are present.

259 G, H, I and K, illustrated in Pl. 14, figs. 7, 5, 3 and 6, are interior fragments which present no unusual features. They might be bits broken from the interior of one of the larger pieces so far as appearances go, though neither they nor any of the other smaller pieces can be fitted together.

259 J, shewn in Pl. 14, fig. 2, is a small crusted fragment showing well-marked veins and troilite inclusions.

THE SHUPIYAN METEORITE.

In the summer of 1913, Mr. C. S. Middlemiss and the late Mr. H. S. Bion of the Geological Survey of India, noticed a meteorite in the

Srinagar Museum, Kashmir. When the desirability of having a specimen of every Indian fall on exhibition in the Imperial collection in Calcutta, was represented to the Durbar, His Highness the Maharajah of Kashmir kindly presented the piece which is the subject of this note. According to Mr. H. S. Bion, who was working in Kashmir at the time and who collected all the available information about the stone, there are two other pieces in the Srinagar Museum, a large one weighing approximately 4,650 gms. and a smaller piece about the same size as the one presented to the Calcutta collection. The latter weighs 294·5 gms. The large piece is said to be complete with no broken surfaces of any size, covered with a black crust showing thumb marks and lines of flow.[1] Mr. Bion believed that the Calcutta specimen was broken off the smaller piece.

The fall is reported to have taken place in May or June 1913, and from another source in April 1912, at Shupiyan, Lat. 74° 50′ : Long. 33° 43′, the specimens being collected by the local police officers and forwarded to the capital of the State. As Shupiyan is a large village with a post office, it is quite possible that the fall may not have occurred in the place itself but somewhere in the surrounding district. No further details of any kind are available.

Description of the Stone.

The general appearance of the specimen can be seen from the photograph, Pl. 16, fig. 1, which is about natural size. It measures 9·4 cms. in greatest length, 6 cms. in greatest breadth and 3 cms. in maximum thickness. It has a specific gravity of 3·670. The surfaces seen in the photograph are crusted, with the exception of the upper right hand corner. The undersurface shows the fracture where it was broken away from the larger mass. This surface though dirty and discoloured is sufficient to prove that the stone is a brecciated grey chondrite, Cgb. The interior is of a light ash-grey colour and the texture firm, exhibiting a few small chondri and rust spots. Since the photograph was taken, the piece has been cut in two for further study, and the smoothed surface of one of the sections clearly shows a fine brecciated structure together with abundant, small, shining grains of nickel-iron collected into a short metallic vein in one place. The chondri are of a darker

[1] After these notes were written Mr. Bion obtained photographs of the big piece. See Pls. 18 and 19.

shade than the groundmass. The large face shown in the shadow on the photograph is covered with a thin, dull black crust which adheres firmly to the interior. Under a lens the crust appears minutely roughened and traversed by a few cracks. The only pittings visible are those on the narrow side face. They consist of two large depressions, approximately 3 cms. in maximum diameter, made up of groups of smaller pits.

Microstructure of the Stone.

Thin sections prove that the stone is coarse-grained, with the chondri, which are mostly circular or nearly so, well differentiated from the groundmass. The latter consists of a coarse granular aggregate of the usual silicates, olivine and enstatite, in the majority of cases considerably rust stained. Irregular grains of nickel-iron are well distributed through the mass, while a few troilite granules and small amounts of a black amorphous substance are also present. Enstatite in felted masses of radiated needles, or minutely crystalline grains, with an occasional inclusion of an olivine granule, and olivine in the grate or barred variety are the common minerals of the chondri. One of the latter contains a tabular, porphyritic, enstatite crystal and a prism of olivine together with smaller orthorhombic pyroxene individuals. A polysomatic chondrule of olivine has the borders of each individual marked off by a narrow opaque zone of greyish inclusions. Fragments of broken chondri have been seen in the groundmass.

THE KAMSAGAR METEORITE.

The Kamsagar meteorite is reported to have fallen in Kamsagar village of the Channagiri taluk, Shimoga District, Mysore, about 1 P.M. on the 12th November 1902. It is stated that a rumbling noise was heard and that the meteorite was quite hot when picked up. With these remarks Dr. W. F. Smeeth, State Geologist in Mysore, forwarded the meteorite to the Geological Survey of India, a gift from the Government of His Highness the Maharajah of Mysore to the Calcutta collection. We have to record our indebtedness to Dr. Smeeth and our obligation to His Highness the Maharajah for this interesting and valuable donation.

The stone is an almost complete individual, of tetrahedral shape, broken into two pieces. It weighs 1,293 gms., and has a specific gravity of 3·526. Resting on the rear face which is the uppermost one in Pl. 16, fig. 2. it measures 9·5 cms. in height, 12 cms. in breadth and 9·3 cms. in thickness, approximately. The general appearance of the stone is perfectly indicated by the photographs and need not be described. The angle of the tetrahedron which formed the front, and which points downwards in the photographs is replaced by a flattened face, marked with a few circular or elongated shallow pits. The crust on two of the tetrahedral faces, seen on the right in Pl. 17, figs. 1 2, is fairly smooth. On the lateral face seen to the left in Pl. 17, fig. 1, the actual crust substance is smoother than elsewhere and there are four well-marked grooves running from the front to the rear of the stone. The crust is thin and dull black with minute, glossy black blebs. On the rear face it is thickened and rougher and has a more scoriaceous appearance. The usual minute shrinkage cracks are well developed and occasionally the crust assumes a brownish-black tinge, more particularly at the bottom of the grooves on the lateral face previously mentioned. The interior of the stone is light ash-grey in colour, with light chondri, fairly abundant specks of nickel-iron and some troilite. The latter mineral tends to congregate in patches, a large one of which is visible at the fracture. It is a typical intermediate chondrite with the formula Ci. It is of a firm texture and takes a good polish.

Composition and Microstructure.

The stone is composed of the silicates olivine and enstatite, with small quantities of a monoclinic pyroxene. and perhaps a little felspar. The other constituents are nickel-iron, troilite and grains of a black, opaque substance which may be of carbonaceous origin. Sections show that the structure as a whole is much coarser grained than that of the Kuttippuram fall. The separation of the chondri from the groundmass is usually evident enough, but not by any means as sharp as in the case of the Shupiyan stone. The chondri are in most cases filled with enstatite (see Pl. 15, fig. 2), in coarse or fine radiated crystal forms; sometimes a filling of cryptocrystalline grains of the same mineral occurs, or even a combination of both these structures. Olivine chondri are rarer, of more irregular outline, and smaller dimensions than the enstatite ones. They are either granular or ribbed and in the latter case appear to be built up of alternating layers of olivine and glass. In the groundmass large porphyritic olivine crystals are common with pieces of chondri, set in a paste of fine silicate grains. Large crystals of enstatite with sharply-defined outlines also occur in the groundmass. Troilite is easily recognised by its bronzy lustre, and, though usually separated, it is sometimes in contact with the irregular nickel-iron grains. Staining of the silicates by decomposition of the nickel-iron is quite common. The black, amorphous substance is found in minute grains and larger irregular pieces, which in one instance includes small olivine grains. When in contact the sulphide sometimes partly envelopes the nickel-iron and thus appears to be secondary to it. Linear inclusions of the black, amorphous body were noticed in one olivine crystal. Minute olivine crystals are also included in the nickel-iron.

Crust sections show three zones: an outer opaque black layer, very thin, and generally removed in the preparation of the slide; an indefinite inner layer, opaque to translucent, containing the remains of silicate grains; and an inner opaque layer with a few, small slag-like pores containing silicates. The inner edge of the innermost layer, although irregular and crenulated, is sharply separated from the rest of the stone. Flattened blebs of nickel-iron occasionally penetrate the crust.

EXPLANATION OF PLATES.

PLATES 7-13.—The Kuttippuram meteorite.

PALTE 14, FIGURES 1-7.—Small fragments of the Kuttippuram meteorite.

PLATE 15, FIGURE 1.—Microphotograph of the granular groundmass of the Kuttippuram meteorite.

FIGURE 2.—Microphotograph of chondri in the Kamsagar meteorite.

FIGURES 3, 4.—Microphotographs showing the intricate vein system of the Kuttippuram meteorite.

PLATE 16, FIGURE 1.—The Shupiyan meteorite.

FIGURE 2.—The Kamsagar meteorite.

PLATE 17, FIGURE 1.—The Kamsagar meteorite.

FIGURE 2.—The Kamsagar meteorite.

PLATE 18.—The Shupiyan meteorite.

PLATE 19.—The Shupiyan meteorite.

PLATE 20.—Map of part of Malabar district, where meteoric stones fell on April 6th, 1914.

THE DENTITION OF THE TRAGULID GENUS *DORCABUNE* BY GUY E. PILGRIM, D.SC., F.G.S., *Assistant Superintendent, Geological Survey of India.* (With Plates 21 to 23.)

The genus *Dorcabune* was founded by the present writer[1] in 1910 for certain upper and lower molars occurring in the Lower Siwaliks of Chinji, referred to the single species *Dorcabune anthracotheroides*.

An additional species was added to the genus in 1912 when I stated[2] that the mandible (G. S. I. No. B.106) figured by Lydekker in *Pal. Ind.*, (10), Vol. II, pt. 5, Pl. 24, fig. 1, under the name of *Anthracotherium silistrense* Pentland, should rather be considered as a species of *Dorcabune* more closely allied to the genus *Dorcatherium* than the species *Dorcabune anthracotheroides*.

The description given by me was brief and it is time that a fuller account of the dentition should be published, especially since much more material has accumulated, and the place of the genus is no longer in any doubt, which might in the first instance have been the case.

The discovery of lower premolars of a species intermediate in size between *D. anthracotheroides* and the one figured by Lydekker by their structure amply confirms my first opinion that the genus was related to *Dorcatherium*. I did not however realize until later how nearly certain forms of the European species *Dorcatherium crassum* Milne Edwards, resembled the Indian genus *Dorcabune* in regard to their brachyodonty and bunodonty. The existence of the double fold in the protocone of the upper molars seems, however, too important a difference from *Dorcatherium crassum* to permit us to place these Indian forms in the same genus as the European species. Moreover the other species of *Dorcatherium* and in particular the Indian species differ markedly by their hypsodonty.

[1] Pilgrim, Notices of new Mammalian Genera and Species from the Tertiaries of India, *Rec. Geol. Surv. India*, XL, p. 68.

[2] Pilgrim, The Vertebrate Fauna of the Gaj Series in the Bugti Hills and the Punjab, *Pal. Ind.*, New Series, IV, Mem. 2, p. 47.

It is possible that this double protoconal fold represents a vestige of an ancestral protoconule, serving to connect the genus *Dorcatherium* with the genus *Cryptomeryx* Schlosser, an affinity which Schlosser has already suggested.[1] I have elsewhere expressed the opinion that the 5-cusped molar arose from a 4-cusped condition, but I am now inclined to defer to Osborn's contrary theory. The similar protoconal folds of *Telmatodon*, *Hemimeryx* and *Choeromeryx* suggest by comparison with *Brachyodus*, *Merycops* and *Hyoboops* a distinct possibility of a fusion of a former protoconule with the protocone.

I propose to assign the various specimens referable to the genus *Dorcabune* to five distinct species, of which the names and stratigraphical horizons may be taken as the following:—

(1) *Dorcabune sindiense*, which occurs in moderate abundance near the base of the Lower Manchhar zone of Sind, but has not been found at higher horizons. It may, therefore, be considered as a tortonian species.

(2) *Dorcabune anthracotheroides*, fairly plentiful in the Chinji zone, but apparently also present in the Lower Manchhar zone of Sind, judging from a fragmentary m_3. It therefore ranges from the tortonian to the sarmatian.

(3) *Dorcabune hyaemoschoides*, also fairly plentiful in the Chinji zone and therefore sarmatian in age.

(4) *Dorcabune nagrii*, apparently characteristic of the Nagri horizon of the Middle Siwaliks, which may be considered as lower pontian.

(5) *Dorcabune latidens* (Syn. *Anthracotherium silistrense* Pentland pars, Lydekker). This species is known by a single mandible figured by Lydekker. As its locality is recorded as Hasnot it seems probable that it occurred in the Dhok Pathan zone of the Middle Siwaliks and may therefore be considered as upper pontian in age.

[1] Schlosser, Beitrage zur Kenntniss der Saugethierreste aus den Süd deutschen Bohnerzen. *Geol. u. Pal. Abhandl.* IX (1912), p. 83.

DORCABUNE ANTHRACOTHEROIDES, Pilgrim.

PL. 21, FIGS. 1, 2, 7, 8. PL. 22, FIGS. 4, 5.

Rec. Geol. Surv. Ind., xl, p. 68 (1910).

This is the largest of the species of *Dorcabune* and far exceeds in size any species of *Dorcatherium*. The type maxilla containing the three molars is figured in Pl. 21 fig. 1, while lower teeth are figured in Pl. 21 figs. 7, 8 and Pl. 22 figs. 4, 5. The dimensions of these teeth are tabulated on pages 235 and 236 along with those of the other species of *Dorcabune* and *Dorcatherium*.

Upper molars.—The most striking feature of these is their brachyodont and bunodont character, which gives them a different appearance from most species of *Dorcatherium* and reminds one rather of an Anthracotheroid such as *Telmatodon*. Even in such a species of *Dorcatherium* as *D. crassum*, in which the actual height of the crown is no greater than in *Dorcabune*, yet a difference is noticeable in the height of the cusps and the shallowness of the valleys which separate the main cones. While the inner cones are truly selenodont the outer ones are quite bunodont and absolutely conical in shape. The rib on the outer side of the paracone and metacone is so broad and prominent as to occupy almost the whole space between the styles. This is especially the case with the rib of the paracone in which the outer surface is in fact entirely rib. This feature is very much less marked even in the most bunodont species of *Dorcatherium*. The parastyle and mesostyle are massive and isolated. The metastyle is much less pronounced. This prominence of the outer styles is characteristic rather of the Anthracotheroids than of *Dorcatherium*. At the same time with wear the mesostyle, instead of showing the loop connecting the paracone to the metacone and belonging equally to both of them, clearly displays its closer union with the metacone, tending to complete with it the postero-external crescent which characterizes *Dorcatherium* and the later ruminants. I am bound to say that the species *Dorcatherium crassum* approaches the genus *Dorcabune* in this particular. The most important distinction between *Dorcabune* and *Dorcatherium* is in the construction of the protocone. This instead of being a simple crescent is more pyramidal in shape and displays three equally strong folds, one proceeding forward and outward, the second backward and outward and a third backward with a tendency sometimes inward and sometimes outward. This structure is identical with that of the upper molars of *Telmatodon*, *Hemimeryx* and *Gonotelma* and, as I have observed above, possibly represents a vestige of an ancestral protoconule, such as *Cryptomeryx*, according to Schlosser, the ancestor of *Dorcatherium*, possesses. It remains only to notice the strong cingulum, which runs on the hinder and front edges of the crown as well as on the inner side, but which is very much more pronounced round the protocone. This often rises into a tubercle between the protocone and the hypocone. The whole surface of the enamel is adorned with a series of moderately fine branching striæ.

Lower molars.—These exhibit almost every essential fold of the enamel which characterizes the lower molars of *Dorcatherium*. The differences between the two genera may be summed up when we say that *Dorcabune* is more brachyodont and bunodont than *Dorcatherium*. This distinction, however, tends to vanish in the species *Dorcatherium crassum*.

The following are the main structural features visible in the various cusps of the lower molars of *Dorcabune*. The two anterior cusps are each so folded on their posterior edges as to form two short ridges, of which the one adjoining the mid line of the tooth joins its fellow of the other cusp. The ridge on the internal side of the tooth soon stops short, that on the external side joins the 2nd external cusp. The anterior arm of the antero-external cusp ends in a broad shelf parallel to the anterior margin of the tooth. Of the two hinder cusps the internal one is conical, sending out only a short process anteriorly in the direction of the mid line between the two anterior cusps, while the external one is crescentic. The anterior arm of the crescent joins the external process of the antero-external cusp; the posterior arm runs inward and completely encircles the posterior base of the postero-internal cusp.

As far as the present species of *Dorcabune* goes, it may be noticed that the fold of enamel which connects the hinder portion of the antero-external cusp to the postero-external cusp is slightly weaker than in any species of *Dorcatherium*. This equally, however, separates this species from the other three species of *Dorcabune*. In *Dorcatherium* there is a tendency for the internal portion of the valley between the first and second lobes of the tooth to be partially blocked by a strong process which connects the inner (*i.e.*, nearer the centre of the tooth) part of the antero-internal cusp with the postero-internal cusp. In side view this process can be seen to project backward from behind the small marginal wing of this cusp. While the inside part of the valley is thus blocked in *Dorcatherium* the marginal portion of the valley is open almost down to the base of the crown. This is less markedly the case in *Dorcatherium crassum* and in *Dorcabune* is not at all so. In the present species of *Dorcabune* the process mentioned above in fact runs toward the inner branch of the antero-external cusp rather than towards the postero-internal cusp.

The species *Dorcabune anthracotheroides* differs both from *Dorcatherium crassum* and from the three other species of *Dorcabune* by its shorter and broader 3rd lobe to m_3. It faces almost entirely forwards and its internal branch almost rests on the base of the internal cusp in front of it, leaving space only for the most minute crenulated tubercle which is slightly extended transversely, but in any case does not display the elongation which occurs in the case of the corresponding inner tubercle of all the species of *Dorcatherium* and also in the other three species of *Dorcabune*. In the Indian species of *Dorcatherium*, *D. majus* and *D. minus*, this 3rd lobe of m_3 faces almost entirely inwards, and its inner branch is much lower than its outer branch, while in *Dorcabune* the two branches are of equal height. This as well as the other characters of *Dorcatheruim majus* mentioned above can be noticed in the mandibular ramus figured in Pl. 23, fig. 2 of the present paper and collected from the Nagri horizon of the Middle Siwaliks at Nagri in the Salt Range.

There is a strong anterior and posterior cingulum on the two front molars and an anterior one on the 3rd molar. Median tubercles are also present at the external entrance of the valleys in m_1 and m_2 and smaller ones in the valleys in m_3.

Lower premolars.—The only positive knowledge we have of the lower premolars in this species is afforded by the 3rd lobe of pm_4 which is *in alveolo* in front of m_1 and m_2 in the specimen (G. S. I. B. 583) figured in Pl. 21, fig. 7. This exhibits a sort of crescent facing inwards and backwards, which seems to agree moderately well with pm_4 of *Dorcatherium crassum* except that the hinder arm of the crescent does not run so far to the inside of the tooth as in that species. It is equally distinct from the pm_4 of *Dorcabune hyaemoschoides* for the same reason. *Dorcatherium majus* and *minus* have a very much smaller and less massive 3rd lobe, which moreover is not crescentic. Still more important is the fact that no inner wing is visible. In *Dorcatherium* such a wing runs backward from the summit and bounds the inner side of a deep elongated cavity, which opens on the postero-internal angle of the tooth. It is of course possible that such a wing exists in *Dorcabune anthracotheroides*, but it does not reach the 3rd lobe. It is, perhaps, more probable that the shape of pm_1 in *Dorcabune anthracotheroides* is more like that of pm_3 in *Dorcatherium* and in *Dorcabune hyaemoschoides.*

We may, perhaps, provisionally assign to this species the fragment from Chinji, figured in Pl. 21, fig. 8 (G. S. I. No. B. 588), which is the front portion of a Tragulid pm_1, as it seems too broad to have belonged to any other.

DORCABUNE HYAEMOSCHOIDES n. sp.

PL. 21, FIG. 6. PL. 22, FIG. 23. PL. 23, FIG. 1.

The type of the present species is the mandible figured in Pl. 23 fig. 1 containing the molars and the last two premolars. The species is decidedly smaller than *D. anthracotheroides.* In the respects in which it differs from that species it approximates to *Dorcatherium crassum.* The depth of the ramus is proportionately greater than in *Dorcatherium crassum.* There is a fairly deep groove starting beneath pm_1 and running backward behind the teeth. Such a groove exists in *Dorcatherium majus* and *minus* and in *Dorcabune latidens*, but not in *D. nagrii.*

Lower molars.—The cusps are less bunodont than in *D. anthracotheroides.* The front arm of the antero-external cusp does not end in a similar broad flat shelf. The 3rd lobe of m_3 is narrower, longer and more pointed. It is also more distant from the 2nd lobe since in addition to the elongated internal tubercle an external ridge connects it with the 2nd external cusp.

Lower premolars.— There is not the same disproportion in length between pm_1 and pm_3 that is the case in *Dorcatherium crasssum*, pm_1 being only slightly inferior to pm_3 in this respect. It should however be observed that pm_1 in *Dorcatherium majus* is also longer than in *D. crassum.*

Pm_1 is a broad tooth consisting of three lobes of which the middle one is the highest and longest and the first and last are nearly equal in length though the 3rd lobe is probably higher when unworn. The latter is very massive and is somewhat crescent-shaped, the crescent facing inwards and forwards, its hinder arm running out to a level with the internal margin of the tooth, in which respect it differs from the corresponding tooth of *Dorcabune anthracotheroides.* A small notch separates this arm from a long wing which runs backward from the summit of the principal cusp and forms the inner wall of the tooth. This wing is separated by a deep, elongate cavity from the crest which connects the principal to the hinder lobe. The stoutness of this 3rd lobe constitutes an important difference from *Dorcatherium*.

Pm_3 is a slightly longer tooth than pm_4. It consists of three lobes, of which the middle one is the highest and longest and the other two are equal in height and size. Neither of them is as stoutly built as in pm_4, but this applies especially to the 3rd lobe. This is crescent shaped, but the hinder arm is much less strong than in pm_4. There is no inner wing on the inner side of the 3rd lobe as is the case in pm_4 although the commencement of an analogous structure may be seen as a slight groove on the hinder side of the principal cusp. On the whole the structure of this tooth would appear to be similar to that of pm_4 in the species *D. anthracotheroides*, so far as we know the latter. The 3rd lobe is however much stouter in the latter species.

Upper molars.—The upper molars of this species seem hardly to differ at all from those of *Dorcabune anthracotheroides* except by the possession of higher and slenderer cusps and a rather less prominent parastyle. The specimen (G. S. I. No. B. 587) figured in Pl. 21, fig. 6, has a small additional fold on the hinder side of the protocone in addition to the three main ones characteristic of the genus.

DORCABUNE LATIDENS n. sp.

PLATE 22, FIGS. 7, 8.

1883. *Anthracotherium silistrense* Pentland *pars;* Lydekker: Indian Tertiary and Post Tertiary Vertebrata, *Pal. Ind.* [10], vol. II, pt. 5, p. 151, Pl. 24, figs. 1, 1a.

1912. *Dorcabune sp.*—Pilgrim: The Vertebrate Fauna of the Gaj Series in the Bugti Hills and the Punjab. *Pal Ind.*, new series, vol. IV, mem. 2, p. 47.

I have referred above to the mandible (G. S. I. No. B. 106), on which this species is founded. It remains only to state my reasons for separating it from the mandible (G. S. I. No. B. 104), which Lydekker first described under the name of *Anthracotherium punjabiense*, but subsequently referred to *Anthracotherium silistrense* Pentland. The latter mandible was figured for the first time by the present writer[1] in 1912 while a better figure is now given in Pl. 22, fig. 6. That specimen is undoubtedly

[1] Pilgrim, The Vertebrate Fauna of the Gaj Series in the Bugti Hills and the Punjab, *Pal. Ind.*, new series, IV, mem. 2, Pl. 14, fig. 2, 2a.

Anthracotheroid and probably belongs to the same species as *Anthracotherium* (?)*Microbunodon silistrense* Pentland. The last lower molar of another mandible (G. S. I. No. B. 596) is shown, double the natural size in Pl. 22 fig. 9. This may also be referred to the species *Anthracotherium Microbunodon*(?) *silistrense* and can readily be compared with m_3 of the present species of *Dorcabune* which is refigured with a similar magnification in Pl. 22, fig. 8. The following important differences exist between the two mandibles. The one which I assign to *Dorcabune* is much deeper and the molars are much broader. The antero-external cusp of the molars possesses on its hinder side the double fold characteristic of *Dorcatherium* and *Dorcabune*, of which the external one runs across the valley to unite with the anterior branch of the postero-external cusp. In the other mandible, as in *Microbunodon*, there is no such double fold on the hinder side of the antero-external cusp, while the anterior branch of the postero-external cusp sends a fold of enamel not to the antero-external cusp, but diagonally across the valley to the antero-internal cusp. Further, in the 3rd lobe of m_3 in the latter mandible the external branch of the crescent runs more inward than in the other so that the arms of the crescent are more squeezed together; moreover there is no inner tubercle.

In structure it corresponds exactly with *Dorcabune hyaemoschoides*, differing from *Dorcatherium* by its bunodonty and brachyodonty, although the distinction between it and *Dorcatherium crassum* is not a great one. It is entitled to specific distinction from *D. anthracotheroides* and *D. hyaemoschoides* on account of its much smaller size. The breadth of its molars and the depth of the mandible distinguish it from each of the other species of *Dorcabune* including *D. nagrii*, which is of approximately the same size.

The upper molars of this species are unknown.

DORCABUNE NAGRII n. sp.

PL. 21. FIG. 5. PL. 22, FIG. 1.

This species is represented by three mandibles showing the molars, and an isolated upper molar. The structure of all these specimens leaves us in no doubt as to its generic identity with *Dorcabune hyaemoschoides*. It is hard, indeed, to find any difference between the two species, except one of size. The cingulum on the upper molar is, however, very faint and the fold on the inner side of the protocone is less well defined. The cusps of the lower molars are, perhaps, rather higher and more slender, approximating to the condition of *Dorcatherium crassum.*

From *D. latidens*, with which it agrees in point of size, it can be distinguished by the smaller breadth of the molars and the inferior depth of the mandible.

DORCABUNE SINDIENSE n. sp.

PL. 21, FIGS. 3, 4.

This species is founded upon two upper molars, two fragmentary last lower molars and five specimens of front lower molars, which were obtained during the field season of 1914-15 from near the base of the Lower Manchhar zone of Sind in the neighbourhood of Bhagothoro by Bankim Behari Gupta, field collector to the Geological Survey. It is approximately the same size as the species *Dorcabune nagrii*, but differs markedly from the Nagri species by its much lower more bunodont cusps, by the stronger development of the parastyle and by the presence of a strong cingulum especially well pronounced on the protocone. The brachyodonty and bunodonty of the genus is much greater in this species than in *D. anthracotheroides* and the parastyle is stronger than in the latter. In fact the resemblance of the upper molar figured in Pl. 21, fig. 3 to an Anthracotheroid such as *Telmatodon* is more than fanciful. The lower molars differ hardly at all in structure from those of the other species of *Dorcabune*. The anterior arm of the antero-external crescent is, however high, rather sharp-edged and narrow and encircles the antero-internal cusp instead of terminating in a low, broad cingulum-like area as is the case in *D. anthracotheroides* and the other species of this genus which have been described above.

The characters of the genus *Dorcabune* may be summarized as follows:—

Artiodactyl allied to *Dorcatherium*, but bearing traces of derivation from a more primitive type such as *Cryptomeryx gaudryi* Schlosser; attaining about twice the size of the largest known species of *Dorcatherium*; dentition more bunodont and brachyodont than *Dorcatherium.*

Upper molars; protocone with a triple fold (? vestigial protoconule), as in some Anthracotheroids *e.g.*, *Telmatodon*, *Hemimeryx*, outer styles and ribs strong and prominent, but mesostyle in wear attached to the metastyle, with a tendency to form a postero-external crescent.

Lower molars; with the double fold on the hinder side of the antero-external cusp characteristic of *Dorcatherium;* process from the hinder side of the antero-internal cusp not prolonged so as to block the inner entrance of the median valley as in *Dorcatherium;* 3rd lobe of m_3 with a inner tubercle, both branches of the crescent equal in height and facing mostly forwards.

Lower premolars ; pm_4 3-lobed ; 3rd lobe massive, crescentic ; a well defined wing proceeding backward from the summit of the 2nd lobe to a varying distance from the hinder margin of the tooth, and separated by a groove or cavity from the crest which connects the 2nd and 3rd lobes. pm_3 slightly longer than pm_4, 3-lobed ; 3rd lobe much less massive than in pm_4; wing not present behind the 2nd lobe, only a shallow groove on its hinder face.

Measurements of Dorcatherium and Dorcabune lower teeth.

		Dorcatherium majus (Nagri mandible G.S.I. B. 593).	Dorcatherium minus (G. S. I. B. 594).	Dorcatherium crassum (Filhol, *Ann. Sc. Geol.* XXI, p. 235.	Dorcabune hyaemoschoides (Chinji mandible G. S. I. B. 585)	Dorcabune anthracotheroides (Chinji mandibles G.S.I.B. 582 and B. 583).	Dorcabune latidens (mandible figured by Lydekker *Pal. Ind.* (10) II, Pl. 24 fig. 1 G.S.I. B.106)	Dorcabune nagrii (G. S. I. B. 591)	Dorcabune sindiensis (G. S. I. B. 601).
M_3	Length	25 0	16 7	18 0	28·7	30·9	23 1	21 7	
	Breadth	11·4	8 3	9·0	14·0	16·0	12·8	11 4	
	Height	14·3	9·0	6 0	10·6	12·2	9 8	10·0	
	$\frac{\text{Height} \times 100}{\text{Length}}$	57·2	53 9	33·3	36 9	39 5	42 4	46 0	
M_2	Length	17·5	12 5	11·0	16 7	19·5	15·1	15 2	14 0
	Breadth	10 9	7 5	8·0	12 6	14·7	12 0	11 0	9 6
	Height	13·3		5·0			9·2		7 1
	$\frac{\text{Breadth} \times 100}{\text{Length}}$	62·3	60·0	72·7	75·4	75 4	79·5	72 4	68 5
M_1	Length	15 7	10·8	11·0	16 2	18 6	13 8		
	Breadth	9·5	6·8	7 0	10 6	11·9	10 0		
	Height			5·0					
	$\frac{\text{Breadth} \times 100}{\text{Length}}$	60·5	63 0	63·6	65·2	64·0	72 5		
Pm_4	Length	17·3	10·0	10 5	16·6				
	Breadth	6·2	4·8	4 6	8·4	8·1			
	Height	8·7		6·0	9·1				
Pm_3	Length	17 7		11·5	17·8				
	Breadth			4·0	6·9				
	Height			5·3	9·1				
Pm_2	Length	14·3		11·5					
	Breadth	4·3		3·7					
	Height	6·4		5·3					
Depth of mandible below front lobe of m_3		28 3	28 1	22	35·5		34 8	29	
$\frac{\text{Depth of mandible} \times 100}{\text{Length of } m_3}$		113·2	168·2	122·2	123·7		150·6	123·9	

Measurements of Dorcatherium and Dorcabune upper molars.

		Dorcatherium majus (G. S. I. No. B. 198 *Pal. Ind.* (10) I. Pl. 7. fig. 4.)	Dorcatherium minus (G. S. I. No. B. 195 *Pal. Ind.* (10) I. Pl. 7. fig. 3.)	Dorcatherium crassum Milne Edwards *Ann. Sc. Geol.* II. p. 147.	Dorcabune hyaemoschoides (G. S. I. No. B. 587.)	Dorcabune anthracotheroides (G. S. I. No. B. 580.)	Dorcabune nagrii (G. S. I. No. B. 590).	Dorcabune sindiense (G. S. I. No. B. 598).
M_3	Length	20·1	11·4	12	18·9	21·4	14·6	14·8
	Breadth	19·2	11·6		21·3	25·8	16·7	16·8
	Height	14·6	9·9		10·3	13·1		6·7
M_2	Length	19·6	10·6	11		21·7		13·4
	Breadth	19·6	12·3			25·7		14·4
	Height							
M_1	Length			10		18·0		
	Breadth					23·1		
	Height							

EXPLANATION OF PLATES.

PLATE 21.

PAGE.

FIG. 1.—*Dorcabune anthracotheroides* Pilg. left maxilla with m_1 to m_3 1 side view from outside, 1a surface view, natural size. From the Lower Siwaliks of Chinji, Salt Range (Geol. Surv., Ind., No. B. 580) 228

FIG. 2 – *Dorcabune anthracotheroides* Pilg. last left upper molar, surface view, natural size. From the Lower Siwaliks of Chinji, Salt Range. (Geol. Surv., Ind., B. 581) . . 228

FIG. 3.—*Dorcabune sindiense*, n. sp. last left upper molar, 3 surface view 3a side view from outside natural size. From the Lower Manchhar horizon of Bhagothoro, Sind (Geol. Surv., Ind., No. B. 598) 234

FIG. 4.—*Dorcabune sindiense* n. sp. a front right lower molar, surface view, natural size, From the Lower Manchhar horizon of Bhagothoro. Sind. (Geol. Surv., Ind., B. 601) . . 234

FIG. 5.—*Dorcabune nagrii* n. sp. last right upper molar 5 surface view 5a side view from outside, natural size. From the Middle Siwaliks of Nagri, Salt Range. (Geol. Surv., Ind., No. B. 590) 233

FIG. 6.—*Dorcabune hyæmoschoides* n. sp. last right upper molar surface view natural size. From the Lower Siwaliks of Chinji, Salt Range (Geol. Surv., Ind., B. 587) 231

PLATE 22.

PLATE 23.

PAGE.

ON HEMATITE CRYSTALS OF CORUNDIFORM HABIT FROM KAJLIDONGRI, CENTRAL INDIA. BY L. LEIGH FERMOR, D.Sc., A.R.S.M., F.G.S., *Superintendent, Geological Survey of India.* (With Plate 24.)

The crystals that form the subject of this note were collected by me at the Kajlidongri manganese-ore quarry early in 1905. They were found in an excavation near cross-cut No. 1 (see Plate 19, *Mem. Geol. Surv. Ind.* Vol. XXXVII) as a small patch in a quartz vein at its junction with the manganese-ore penetrated by the vein. Except at this one spot the quartz vein carried crystals of hollandite.

The crystals were investigated crystallographically in Calcutta and found to belong to the hematite group of minerals. The total amount of material in my possession was very small, but one crystal was sacrificed and examined by the ordinary methods of qualitative chemical analysis, iron being the only element detected. From this it was concluded that the mineral must be hematite in spite of its unusual crystallographic habit.

In 1914, when at Cambridge on Study Leave from India, I took the opportunity to resume my examination of this material; and at this point I must take the opportunity to express my indebtedness to Prof. W. J. Lewis for the facilities granted me of working in the Mineralogical Laboratary, and to Dr. A. Hutchinson for kind help given me in the study both of these hematite crystals and of the hollandite crystals to be discussed in another paper.

The material available consists of (1) a specimen about 3 cm. square showing about 10 crystals of hematite, which range up to $3\frac{1}{2}$ mm. diameter on the basal plane and 5 cm. in length, and rest in association with quartz on very fine-grained manganese-ore, consisting of psilomelane with a little admixed finely crystalline braunite; (2) a small piece measuring 14 mm. × 8 mm. and showing about a dozen hematite crystals ranging from 1 to

3 mm. across the basal plane; and (3) some half a dozen loose crystals broken off the foregoing specimen for purposes of measurement.[1] The whole of this material is registered in the collections of the Geological Survey of India as J. 956.

As will be seen from the sequel, these crystals show a series of steep hexagonal pyramids truncated by the basal plane, with a few minute bevelling rhombohedral faces, and a narrow equatorial zone of prism faces of the same order as the pyramids. The crystals are implanted and, therefore, only singly terminated, with one single exception, where the crystal is lying on its side on the surface of specimen No. 1. The lustre of many of the crystals is splendent, particularly on the basal plane and the faces of the chief pyramid *x* (6 1 4): consequently, in spite of a network of fine lines due to lamellar twinning parallel to the fundamental rhombohedron, these crystals have afforded excellent images, giving data suitable for the calculation of the value of the axial ratio.

The forms identified.

The goniometric measurements are summarised in the two following tables, the first giving the data relative to the zone (*ca*) or $[1\bar{2}1]$, which may be termed the bipyramid zone, and the second the data relative to the rhombohedral zones *cr* or [0 1 1] and (*cn*) or $[\bar{1}10]$. In the bipyramid zone the principle forms present are the basal plane *c* (111) and the bipyramid of the second order *x* (6 1 4). In addition there is a succession of bipyramids of the second order represented by a series of narrow faces and parallel striations. Amongst these the form *z* (7 1 5) is at times well developed, whilst the forms *X* (5 1 3), (29 1 27) and (51 1 49), are almost certainly present: the two last are new forms to which the letters *S* and *I* have been assigned. In addition there are numerous other linear reflecting bipyramid faces, giving images that are usually very faint and blurred, rendering the readings uncertain, and making it difficult to decide to which of two possible forms a given reading should be referred. Consequently, although it is almost certain that some of these additional forms really exist on the crystals studied, yet each of them must be regarded as doubtful.

[1] These are referred to as crystals Nos. 1 to 6 in this paper, and a crystal measured on specimen (2) is No. 7.

TABLE 1.

List of faces in the bipyramid zone ca.

	Letter symbol.	Symbol referred to rhombohedral axes.	Symbol referred to hexagonal axes.	Angle with c or 111.				
				MEASURED.			CALCULATED.	
				Number of readings	Range.	Mean.		
Basal plane	*c*	(111)	(0001)	--	—	-	0°0′	Present.
Hexagonal bipyramids of the second order	*X*	(51$\bar{3}$)	(44$\bar{8}$3)	3	74°49′—75°8′	74°58′	74°28′	Present.
	V	(11·2·$\bar{7}$)	(33$\bar{6}$2)	1	76°2′	76°2′	76°8′	Uncertain
	ι	(61$\bar{1}$)	(5·5·$\overline{10}$·3)	17	77°11′—77°40′	77°28′*	77°28′	Present
				8	77°16′—77°55′	77°36′	77°28′	Below equator
		(13·2·$\bar{9}$)	(11·11·$\overline{22}$·6)	4	78°17′—78°45′	78°30′	78°34′	Uncertain: new
	z	(71$\bar{5}$)	(22$\bar{4}$1)	20	79°7′—80°3′	79°36′	79°30′	Present.
		(15·2·$\overline{11}$)	(13·13·$\overline{26}$·6)	3	80°21′—80°35′	80°29′	80°18′	Uncertain: new
	*k*₁	(81$\bar{6}$)	(7·7·$\overline{14}$·3)	3	80°17′—81°9′	80°58′	80°59′	do.
		(17·2·$\overline{13}$)	(33$\bar{5}$1)	1	81°31′	81°31′	81°34′	do. new
	*k*₄	(91$\bar{7}$)	(8·8·$\overline{16}$·3)	2	82°4′—82°23′	82°14′	82°5½′	do.
		(11·1·$\bar{9}$)	(10·10·$\overline{20}$·3)	2	83°19′—83°39′	83°29′	83°39	do. new
		(12·1·$\overline{10}$)	(11·11·$\overline{22}$·3)	1	84°25′	84°25′	84°14′	do. new
		(18·1·$\overline{16}$)	(17·17·$\overline{34}$·3)	3	86°17′—86°22′	86°19′	86°16′	do new
	S	(29·1·$\overline{27}$)	(28·28·$\overline{56}$·3)	7	87°18′—88°9′	87°40′	87°43′	Present: new
	I	(51·1·$\overline{49}$)	(50·50·$\overline{100}$·3)	5	88°40′—88°48′	88°44′	88°44′	do. new
Hexagonal prism of second order	*a*	(10$\bar{1}$)	(11$\bar{2}$0)	12	89°37′—90°36′	90°2′	90°0′	do.

Table 2.

List of forms in the rhombohedral zones cr and cη.

	Letter symbol	Symbol referred to rhombohedral axes.	Symbol referred to hexagonal axes.	Angle with *c* or 111. Measured. Number of readings.	Measured. Range.	Measured. Mean	Calculated.	
Basal plane	*c*	(111)	(0001)	—	—	—	0°0′	Present.
Rhombohedra :—								
Direct	*r*	(100)	(10$\bar{1}$1)	3	57°29′—58°23′	57°55′	57°18′	Present.
Inverse	η	(22$\bar{1}$)	(10$\bar{1}$1)	2	56°50′—59°44′	58°17′	57°18′	do.
Do.		(17·17·5)	(4·0·$\bar{4}$·13)	1	25°33′	25°33′	25°36′	Uncertain : ne
Do.	*l*′	(28·28·13)	(5·0·$\bar{5}$·23)	8	18°15′—18°52′	18°37′	18°43′	Present : ne
Do.		(25·25·13)	(4·0·$\bar{4}$·21)	1	16°18′	16°18′	16°32′	Uncertain : ne
Do.		(25·25·14)	(11·0·$\bar{11}$·64)	1	15°6′	15°6′	14°59′	do. ne
Do.		(771)	(10$\bar{1}$6)	1	14°36′	14°36′	14°33′	do. ne
Do.		(33·33·20)	(13·0·$\bar{13}$·86)	1	13°29′	13°29′	13°15′	do. ne
Do.		(885)	(10$\bar{1}$7)	1	12°10′	12°10′	12°33′	do.
Do.		(332)	(10$\bar{1}$8)	1	10°42′	10°42′	11°1′	do.

The prism of the second order *a* (10$\bar{1}$) is represented by one of these narrow faces, and separates the pyramid faces above the equatorial section of a crystal from those below, where developed. In the table No. 1 on page 241, the readings for pyramid faces below the equator have been grouped with those above, except in the case of the form *x* (614), where the two sets of readings have been separately averaged. In the equatorial zone of these hematite crystals there is often an oscillation of forms causing re-entrant angles, and the resultant repetition of the same form helps to blurr the goniometric reflections.

Indications were obtained of the presence of no less than 11 rhombohedra, amongst which are both the direct and inverse forms of the fundamental rhombohedron, very minutely developed when present and consequently giving very poor reflections. The sorting of these readings between the direct and inverse forms *r* (100) and η (22$\bar{1}$) is, of course, a matter of convention. The presence of twinning lamellae parallel to the fundamental rhombohedron has already been mentioned: it was decided to regard these as parallel to the direct form, this convention converting all the other rhombohedra present into inverse forms, of which one is conspicuously developed on several of the crystals. The faces of this form are dull and striated as shown in Plate 24, fig. 2, but there is little doubt that they represent a new form (28.28.13) or ($5.0.\bar{5}.23$), to which the letter *U* may be assigned. The other, very uncertain, rhombohedra mostly lie between the above form and the basal plane and are apparently the cause of the striation of *U*.

Plate 24, fig. 1, is a stereogram of the Kajlidongri hematite, in which are inserted all the forms the presence of which is fairly certain. The most important of these are shown in figure 2 illustrating the habit of the mineral.

Twin lamellae.

As has already been mentioned the faces of these crystals are traversed by fine striations, which, as seen on any face of the form *x*, consist of three parallel series; study with a lens shows that the three series are parallel to the three faces of one of the fundamental rhombohedra, which is taken as the direct form *r* (100). This observation was confirmed by calculating the angles made by the traces of each of the faces 100, 010, and 001, on the face $6\bar{4}1$, with the edge between $6\bar{4}1$ and 111, and comparing the calculated with the measured values. The measurement was effected by supporting a crystal with wax on a glass slide on the stage of a rotating-stage microscope. The horizontality of the face to be observed was judged by eye and the angles measured by means of the ordinary cross-wires of the microscope. The measurements, though somewhat rough, were sufficiently accurate to confirm the conclusion that the striae are due to twinning parallel to the fundamental rhombohedron, as may be judged from the following statement:—

Striations on $6\bar{4}1$.	Angle with edge between $6\bar{4}1$ and 111.			
	MEASURED.			Calculated values.
	Number of readings.	Range.	Mean.	
Parallel to *r* (100) .	7	47°12′—50°24′	48°59′	48°44′
do *r′* (010) .	7	31°23′—32°10′	31°28′	31°32′
do. *r″* (001) .	6	57°58′—59°30′	58°24′	57°55½′

The measurements were carried out on crystals Nos. 1 and 2.

The faces of the form x (614) often show a few striae parallel to the edge between 614 and 111. Whether these are due to an oscillatory combination with other forms in the bipyramid zone or are due to parting parallel to c is unknown.

The faces of both the chief forms c and x have given many fine images, and consequently the angle cx has been selected for use in the computation of the axial ratios of the mineral.

The axial ratio of hematite.

On the 7 crystals measured 21 readings of the angle cx were obtained above the equator. Of these 4 were rejected; the remaining 17 were :—

Crystal No. 1	77°20½′, 21′
„ No. 2	77°13′, 20′, 30′
„ No. 3	77°11′, 35′, 39′
„ No. 4	77°40′, 30½′, 31′
„ No. 5	77°24½′.
„ No. 6	77°35½′, 31′
„ No. 7	77°29′, 31½′, 32′

These give a mean of 77°28′. If only 7 of these readings, namely 77°30′, 30½′, 31′, 31′, 29′, 31½′, 32′, be utilised, the average becomes 77°31′.

Considering the brilliance of some of these crystals and the fine images in many cases, the differences in the foregoing readings are surprisingly large. Of these readings 77°20½′ and 77°21′ on crystal No. 1, and 77°30½′ and 77°31′ on crystal No. 4, are very good values indeed; and it appears, unlikely as it may seem, that there is a distinct difference between these two crystals. The average figure 77°28′ has consequently been adopted. This gives a value for the ratio $a : \dot{c}$ of 1 : 1·3495, and for the fundamental angle cr of 57°18′ 26″.[1] As a check on the angle 77°28′ we have the measured values of xx', which are 58°40′, 24′, 26′, 39′, 25′, 11′, 31′, 31′, 27′, 47′, 18′, 3′, with a mean value of 58°27′. Of the above, the four best readings were 58°24′, 25′, 31′, 31′, with a mean value of 58°28′.[2] The value of xx' calculated from cx = 77°28′ is 58°26′.

It will be interesting to compare this value for the axial ratio of the Kajlidongri hematite with the corresponding figures for

[1] The mean of the two fine readings on crystal No. 1, namely, 77°20¾′, gives the value 1·3362, whilst the mean of the two fine readings on crystal No. 4, namely 77°30¾′ gives a value of 1·3546, for the vertical axis.

[2] If this were the true value then the value of $\dot{c}$ would be 1·3664, which is close to Melczer's value (see page 245).

hematite from other localities; and for this purpose we cannot do better than consult G. Melczer's paper 'Ueber die Symmetrie und das Axenverhältniss des Hämatit'.[1]

He first compares the results of previous investigators, showing that their results do not agree, the best previous values being:—

According to	Kokscharow	1	:	1.3652 ± 0·0005.
Do.	Vater	1	:	1.3642 ± 0·0015ca.
Do.	Schweitzer	1	:	1.3605
Do.	Miller	1	:	1.3594

In view of this disagreement Melczer secured hematite crystals from several well-known localities and determined their axial ratios. He summarises the results as follows (*l.c.*, p. 599):—

Locality.	*a.*		*c.*	Observer.
Framont, Alsace	1	:	1.3608	Schweitzer and Melczer
Altenberg, Saxony	1	:	1.3619	Melczer
Artificial crystals	1	:	1.3642	Vater
Dognácska, Hungary	1	:	1.3651	Melczer
Elba	1	:	1.3652	do.
Cavradi, Switzerland	1	:	1.3652	do.
Vesuvius	1	:	1.3652	Kokscharow
Do.	1	:	1.3654	Melczer
Do.	1	:	1.3656	do.
Hargita, Transylvania	1	:	1.3655	do.
Tavetsch, Switzerland	1	:	1.3693	do.

From the almost identical values obtained for the hematites from the five localities, Dognácska, Elba. Cavradi, Vesuvius, and Hargita, Melczer deduces the mean value of the axial ratio to be 1 : 1·3654 ± 0·0002, and on the basis of analytical data relative to the hematite from Elba and Hargita he deduces that the foregoing figure is the axial ratio for pure hematite. It seems necessary to suppose, therefore, that the hematites with different axial ratios, such as those of Framont, Altenberg, and Tavetsch, must contain an appreciable amount of enclosed impurity. Unfortunately, enough material was not available to allow this point to be tested satisfactorily.

If the axial ratio of the Kajlidongri hematite be compared with those in the foregoing list it will be seen that it is considerably lower than any of those recorded by Melczer. It must, therefore, be assumed that the Kajlidongri crystals contain some impurity, which, considering their mode of occurrence, may well be an oxide

[1] *Zeitsch. Kryst.*, XXXVII, pp. 580—602, (1903).

of manganese in solid solution. But, again, it would be difficult to confirm this point, firstly because of the small amount of material in existence, and secondly because, if some of the crystals were sacrificed for this purpose, it would be impossible to be sure that the material was free from mechanically enclosed manganese minerals.

Although none of the values of $a : \dot{c}$ listed above is very close to the Kajlidongri value, it is interesting to notice that the mean (57°19½′) of the values of the angle *cr* (ranging from 56°42′ to 57°52′) recorded by Bücking for 6 types of hematite from the Binnenthal is close to the value calculated for Kajlidongri (57°18½′)[1].

Comparison with French hematites of corundiform habit.

A comparison of figure 2 of Plate 24 with the figures of hematite given in text-books (*e.g.* Dana) shows at once that we have to deal with hematite of unusual habit: and in fact a search in likely places has not led to the discovery of any figure of this mineral showing the form *x* $(61\bar{4})$, which is the dominant form in the Kajlidongri cystals. The nearest habits figured are two given by Prof. Lacroix in his 'Minéralogie de la France et de ses Colonies'. Fig. 29 on page 273 of Vol. III shows a hematite crystal from Blattenberg near Sainte-Marie aux-Mines in France, the principal form present being the less steep bipyramid of the second order *n* (311), a form not detected on the Kajlidongri crystals. Fig. 19 on page 266 of the same volume, representing a crystal of hematite from Pouzac in the department of Hautes-Pyrénées, is very similar in general aspect to the Indian crystals; but, in place of the form *x* $(61\bar{4})$ so characteristic of the Indian crystals the principal form in the mineral from Pouzac is *z* (715), which is a subordinate form on the Kajlidongri hematite, whilst *x* is absent. The Pouzac hematite also shows the prism *a* (101), the basal plane *c* (111), and the direct and inverse rhombohedra *r* (100) and *n* (221), all present in the Indian crystals, and in addition thin bevelling faces of the form *n* $(31\bar{1}$,) absent from the Kajlidongri mineral. The resemblance between the hematites of Pouzac and Kajlidongri is so striking because the forms *x* and *z* are very close to one another, making angles of 77°28′ and 79°30′ respectively with *c*. The resemblance of the hematite crystals from both these localities to a common form of

[1] *Zeitsch. Kryst.*, I, pp. 565-574, (1877), and II, p. 421, (1878).

corundum is evident at once, and the likeness is heightened in the Indian case by the presence of twin lamellae parallel to *r*, and of the horizontal striae, not shown in my figure, which may represent parting planes parallel to *c*. Lacroix compares the Pouzac hematite with corundum from Haute Loire.

In spite, however, of this striking resemblance of the Kajlidongri hematite to corundum, it is interesting to notice that its principal and most characteristic form *x* (61 4) has not yet been satisfactorily identified on corundum crystals.

ERRATA.

PAGE 76, LINE 22, for *guadrata* read *quadrata*.
" 77 " 18, place *R. furcillata Dav. series* opposite *Furci-rhynchia*.
" 77 " 1, 2 from bottom, for *Caplalæ* read *Capillatæ*.
" 78 " 28, for *sphæroidothyri* read *sphæroidothyris*.
" 78 " 31, for *Plectothyri* read **Plectothyris*.
" 78 " 32, for *Plectoidothyr* read *Plectoidothyris*.

RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

Part 4.] 1915. [December

GEOLOGY OF THE COUNTRY NEAR NGAHLAINGDWIN, MINBU DISTRICT, BURMA. BY DR. CESARE PORRO (WITH GEOLOGICAL MAP BY C. PORRO AND R. LEWER *formerly Geologists to the British Burma Petroleum Co.*,[1] AND WITH FOOTNOTES AND APPENDIX BY G. DE P. COTTER, *Geological Survey of India*). With Plates 25 and 26.

INTRODUCTION.

THIS paper is accompanied by a map and sections showing the sequence of strata, and the structure. The various subdivisions, which will afterwards be correlated with the horizons of other mapped areas of Burma, are as follows in ascending order :—

Subdivision 1. Massive sandstones of the Nwama Taung.

Subdivision 2. Lignite-bearing shales, with sandstones.

Subdivision 3. Alternations of sandstones and shales with beds containing foraminifera.

Subdivision 4. Sandstones and shales.

Subdivision 5. Massive sandstones with interstratified shales, forming the foothills of the Nwama Taung.

Subdivision 6. Kinmungyon shales, probably equivalent to the *Lepidocyclina theobaldi* clays in south Minbu, which G. deP. Cotter [2] regards as the equivalents of the Sitsayan shales of Theobald.

[1] I am indebted to the British Burma Petroleum Co., Ld., for permission to publish this paper.—EDITOR.

[2] See G. deP. Cotter, the Pegu-Eocene Succession in the Minbu district near Ngape, *Rec. Geol. Sur. Ind.*, XLI, p. 232 ; Theobald, *Mem. Geol. Sur. Ind.*, X.

Subdivision 7. Upper alternations of sandstone and shale. Only the lower part of this subdivision is shown on the map. It consists from base upwards of (1) a zone of sandstones, (2) shale, (3) sandstones and conglomerates with shales, (4) a thick series of sandstone and shale, which is overlain by the basal conglomerates of the Irrawaddi series.[1]

Stratigraphically the area may be divided into :—

(*a*) The Nwama Taung monocline.

(*b*) The median syncline.

(*c*) The Ngahlaingdwin anticline.

Fossils were collected only from subdivision 3.[2]

The topographical map published by the Survey of India being of too small a scale (1 inch = 1 mile) for our purpose, the chief lines, such as roads and streams were surveyed with a plane table by our assistant Mr. Rosario, while the remaining details were filled in by Mr. R. Lewer and myself by means of pacing and pocket-compass.[3] Our measurements, after due checking, proved to be sufficiently approximate.

(*a*) THE NWAMA TAUNG MONOCLINE.

1. *Watershed.*

The main ridge of the Nwama Taung extends in a straight line from south south-east to north north-west, and rises about 1,200 ft. from the surrounding country. It is built of massive sandstones (subdivision 1) of grey colour, and of a uniformly medium grain structure. Beds of hard rock with a thickness of from 1 yard upwards, are more prevalent than thinner strata, while shale and marl was not seen. The character and dip of the rocks determine the surface relief. Only this massive sandstone outcrops on the main

[1] Dr. C. Porro's seven sub-divisions of the Tertiaries near Ngahlaingdwin can now be correlated, (thanks to the work of my late colleague H. S. Bion) with the sub-divisions adopted by the Geological Survey for the Burma Tertiaries elsewhere. Thus his subdivision 1 is the Pondaung sandstone stage (see *Rec. Geol. Sur. Ind.*, XLIV, p. 164), his 2 and 3 taken together constitute the Yaw stage (*Rec. Geol. Sur. Ind.*, XLIV, pp. 52 and 164), his 4 and 5 are the Shwezetaw sandstones (*Rec. Geol. Sur. Ind.*, XLIV, p. 164), his 6 is the Padaung Clay (*Rec. Geol. Sur. Ind.*, XLIV, p. 164), and his 7 is equivalent to the Pegu stage, using this latter term in a *restricted* sense (see *Rec. Geol. Sur. Ind.*, vol. XLIV, p. 164), while if the term Pegu be used in the broad sense defined by E. H. Pascoe (*Mem. Geol. Sur. Ind.*, XL, p. 14) or by myself in a previous paper (*Rec. Geol. Sur. Ind.*, XLI, p. 221), it would include both the Padaung Clays and the Shwezetaw sandstones. G. deP. C.

[2] NOTE.—This horizon is characterised by *Nummulites yawensis* and *Orthophragmina sella* (*Rec. Geol. Sur. Ind.*, XLIV, p. 81). G. de P. C.

[3] The map, which was originally drawn to a scale of 8" = 1 mile, has been reduced for reproduction to a scale of 2" = 1 mile —EDITOR.

ridge, the strike coincides with the direction of the range, that is, it runs to about north 25° west and dips to east 25° north at an angle of from 50° to 80°. On the precipitous western scarp, the sandstone beds are well exposed, east of the ridge the ground is less steep, and one sees numerous subsidiary ridges capped with sandstone rising parallel with the crest.

2. *Section E.—E.* (*Plate* 25) *from west to east through Kinmungyon village.*

This section commences a short distance north of the trigonometrical point 1950, and on the eastern slope of the Nwama Taung passes through the sandstones of subdivision 1, in which large pieces of fossil wood, similar to that so frequently seen in the Irrawaddy series, were found.

The dip is steep to vertical in an easterly direction. A tributary of the Kinmungyon Chaung[1] shows in this area the frequent waterfalls that characterise this subdivision. Some springs which have incrusted the sandstones with travertine were here observed.

This tributary, after passing over a bed of massive sandstone, commences to traverse the low-lying ground underlain by subdivision 2, which is mainly shale. The shales break with a conchoidal fracture and are either not visibly stratified, or else, more frequently, thin-bedded, with very thin intercalations of sandy shale; the colour is dark to light bluish grey.

Lignite layers from 1 to 3 feet in thickness characterise this subdivision. The lignite is a bright black and breaks into small pieces; sometimes it contains intercalations of clay partings, and changes laterally and gradually into shale. Such shales are for many yards of a dark colour and highly carbonaceous. Outcrops of lignite beds are marked in our sections in black.

Intercalations of siliceous limestone are also frequent in the shales; they are from 1 to 2 feet thick and project with sharply defined contours from the soft shale; the colour at the surface is yellowish red, but in the interior is dark blue.

The sandstones which are occasionally interbedded with shale in subdivision 2 do not materially differ from those of sub-division 1. They occasionally show lenticles of lignite, a few inches in thickness. Sandstones are never thick in subdivision 2. The dip in this area is at about 70° to east-north-east.

[1] *Chaung*, stream.

Subdivision 2 contains oil. In the above-mentioned stream section, an oil seepage was found about 150 feet above the highest lignite layer. The oil issues from a bed of sandstone of medium grain. There is no sign of bituminous matter in the rock. The oil is seen in an iridescent film lying on the surface of a pool of water. The smell is distinct. The seepage was previously unknown to the Burmans. The dip is about 50° to east 25° north.

In a small tributary stream, we found another oil seepage at a distance of about 600 feet and in a direction north 20° west from the former. Here is a small pool with thick iridescent films between two beds of sandstones dipping steeply to east 25° north. One of these is dry, while the other shows numerous irregular veins of blackened sand and bituminous matter.

This oil-bearing sandstone is on the same level as the former seepage, but if the strike were continued, it should be about 20 feet higher in the sequence.

Efflorescent salt is also seen in the oil horizon. It is also found in the upper part of subdivision 1, in which (as we shall afterwards see) the earliest oil indications occur.

250 feet below the oil seepage, the chaung enters subdivision 3. This consists of shale and sandstone in repeated layers. The shale resembles those of the underlying subdivision. The sandstones are characteristic through their red colour, their weathered surfaces, and the abundance of foraminifera, corals and molluscs. Small nummulites and orthophragminæ were found.

The chaung now passes through sub-division 4. This is also a succession of shale and sandstone with some hard siliceous layers. Here also the ground is low-lying. Subdivision 5, composed of massive sandstones, forms a prominent ridge of foot-hills; this ridge is continuous for longer distances than is indicated in the topographical map (sheet 84 L.-6 Burma Surveys). In reality only large chaungs such as the Kinmungyon and Kywe-u chaungs break through this chain. Here are exposed massive sandstones coated with efflorescent salt. They occasionally contain fossil wood. There is a shale band 20 feet thick in their middle. The total thickness may be about 1,000 feet. Above this a flat belt of country about 400 feet wide is probably underlain by shale. Above this comes another sequence of massive sandstones about 750 feet thick, through which the Kinmungyon Chaung forms a gorge, whence it emerges into the open country around Kinmungyon village, which is underlain by the so-called Sitsayan Shales of subdivision 6.

3. *Section N.—N. from west to east, as far as Kywe-u village.*

This is also a good section ; subdivision 3 is highly fossiliferous here. Subdivision 1 shows the same features as in the preceding section. In subdivision 2 the intercalated sandstones are more prevalent resulting in increased height of the foot-hills. Subdivision 4 is badly exposed. In subdivision 5 the sandstones contain more intercalated shale ; hence they do not form the typical hill-ridges seen in the former section. The angle of dip has become more gentle ; it is 50° at the watershed and diminishes to 35° in subdivision 5 Kywe-u is built upon the shales of subdivision 6 as is the case with Kinmungyon village ; in either case the open plain is formed by the underlying shales.

4. *Section M.—M. from west to east (southern part of map).*

Subdivision 1 was visited, but lies outside the limits of our map. It presents the usual features. Above the lignites of subdivision 2 was found an oil seepage forming a water-pool with an iridescent film of floating oil. Proceeding eastward down stream subdivision 3 is seen to contain fossiliferous beds, especially sandtone filled with coral, but owing to the short time at our disposal, we could not make a search for foraminifera.

Below this, the stream traverses sandstones and shale which we assign to subdivisions 4 and 5, after which the open country is reached.

(b) THE MEDIAN SYNCLINE.

1. *Section E.—E.*—continued.

The plain of Kinmungyon, although not much more than 1,500 feet in width, extends several miles in a south-south-east—north-north-west direction. At Kinmungyon village, the exposures of subdivision 6 show merely blue grey shale and marl without evident stratification, and breaking with conchoidal fracture. But occasionally some thin intercalations of sand occur ; these show a dip of about 40° to east-north-east.

The total thickness is over 1,000 feet. From the stratigraphical position of this subdivision with respect to subdivision 3, I believe it to correspond to the *Lepidocyclina theobaldi* shales of G. deP. Cotter (see *ante*). This subdivision continues without lateral change throughout the entire area examined, forming flat or low-hilled, country, which contrasts with the sandstone slopes on both sides. The valley formed by the shales runs from Kinmungyon to Kywe-u between the foot-hills of the Nwama Taung and the ridge formed by the sandstones forming the base of subdivision 7. Kinmungyon pagoda lies upon these sandstones, which there dip at 35° to east-north-east.

To the sandstones of the base of subdivision 7 succeeds a very continuous band of shales, then sandstones again containing layers with cherty red pebbles and with white quarry pebbles, passing into red conglomerates. These layers are about 500 feet from the base of subdivision 7.

At the junction of the Kinmungyon and Thayu streams, the dip has diminished to about 5°.

Proceeding up the Thayu stream from the junction, the eastern limb of the syncline is exposed and about 750 feet distance from the junction, dips of 45° to 50° are seen in massive sandstone.

In order to continue the section, the exposures in the stream which runs from the oil wells westward to the Thayu stream may now be described.

Proceeding up this tributary from its confluence with the Thayu, one sees the sandstones of subdivision 7, dipping westwards at angles of from 40° to 50°. Further east the shales of subdivision 6 are found.

The correspondence on both sides of the syncline is complete, except that I have not found the conglomerates of subdivision 7 in the eastern limb. There is supposed to be an indication of oil in this stream from the sandstones of the base of subdivision 7 exposed on the eastern limb of the syncline, but we did not find clear indications.

2. *Along the synclinal axis.*

South of its junction with the Kinmungyon stream, the Thayu stream flows for two miles along the syncline, repeatedly crossing and recrossing the axis. The correspondence of both sides is distinct. The bend is very sharp, so that in the space of about 2 yards the almost flat strata acquire a dip of about 45°. The strata are here in thin beds; on the east one observes a remarkable reduction in thickness, due to squeezing and slickensiding; real faulting does not exist.

For three quarters of a mile south of the junction, we have not seen the strike lines converging on either side of the synclinal axis; therefore we suppose the axis to be horizontal. But further south convergence is noticeable. As the measurements are far from being geometrically exact, we cannot say how much the axis rises, although we know it to be rising. North of the section L.-L., on the east-west bend of the stream, the sequence from the synclinal axis eastwards to the base of subdivision 7 is very clear. On comparing this section with that described above (page 253), we conclude that the axis rises about 500 feet between the two points.

This figure, however, is approximate, since the strata, being squeezed by pressure, do not show the true thickness. In this section, where the Thayu stream runs east-west, on both sides of the axis sandstones with reddish yellow cherty pebbles, passing into red conglomerate similar to that mentioned above, can be observed. Similar conglomerates were found in the lower part of the Thayu Chaung east of Ngahlaingdwin, beyond the limits of our map. These horizons approximately correspond with one another.

Further south, the country south-south-east of the Thayu Chaung has not been sufficiently explored, but we have observed that at least as far as our section M.—M. the synclinal axis continues to rise steadily.

(c) THE NGAHLAINGDWIN ANTICLINE.

The map and sections clearly show the rise of the anticline to the north, the convergence of each geological subdivision to the south, and its division northwards into two outcrops flanking either side of the anticline. It will therefore be convenient to describe each subdivision, beginning with the newest, and starting from the southern part of the map.

Subdivision 7 (The sandstones overlying the Kinmungyon shales).—South of the section M.—M., these sandstones are folded in an arch which forms the southern end of the Ngahlaingdwin anticline, the crest of which sinks to the south at an angle of about 10°. The sandstones slope gradually southwards under a covering of shale, but to the north the emergence of the Kinmungyon shales (subdivision 6) from beneath them gives rise to an abrupt scarp. From this point it is easy to follow the sandstones east and west of the axis.

On the eastern side, the outcrop runs north-north-east till it passes the Thayu Chaung; it dips here at angles of from 20° to 25°.

East of the sandstones the ground is low owing to the presence of shales overlying. On the west is a steep slope from them to the low ground of the Kinmungyon shales. In the Thayu Chaung the dip of the sandstones is from 35° to 40° to east.

North of the Thayu Chaung the scarp and dip slopes of these sandstones enable them to be easily traced, and the ridge which they form can be seen from the hills to the west. In the north of the map, they are cut through by the Zaha Chaung , the dip in this area is greatly increased, being about 88° to east. On the western limb of the anticline, the outcrop of these sandstones extends first west-north-west, then north-west, then north-north-west. The dip is steeper upon this side and gradually approaches 80°. In this area the sandstones do not form a ridge, but there are numerous small billowy outcrops.

Northwards from section L.—L., the sandstones are not indicated by the orography as is the case in the eastern outcrop. One repeatedly observes this difference in orography between the east and the west of the anticline ; in the west also the tributary streams run to the dip, while on the east they run along the strike of the rocks. They flow into the Zaha Chaung in the north and the Thayu in the south. It follows that west of the anticlinal axis, the orography is less distinct.

Subdivision 6.—I have already described how these shales emerge in the south from the capping arch of sandstones, and how their upper boundary is indicated by the sandstone scarp. Outcrops are rare, since there is a heavy soil cap. and dense bamboo jungle. The ground is flat or has irregular low hills. Only the Thayu Chaung cuts deep enough to show really good exposures. The section recalls that of the Kinmungyon Chaung. The section through the Thayu Chaung shows clearly the marked asymmetry of the anticline, since these shales dip much more steeply on the west than on the east. As a result the outcrop is much narrower on the west. On the eastern flank, although outcrops are rare, the Kinmungyon shales can easily be recognised owing to the topography.

They form the cultivated ground at Ngahlaingdwin and are continued in a valley to the north.

This valley is 1,500 feet wide approximately. If the shales dip at 40°, as may be assumed from the dip of the sandstones above and below, their thickness must be about 1,000 feet.

About 2 miles north of Ngahlaingdwin, the valley if terminated by a ridge uniting the sandstones of subdivision 7 with those of subdivision 5. But further north another longitudinal depression continues to the Zaha Chaung along the outcrop of shales. The dip here increases from 40° to 88° at the Zaha Chaung.

On the western flank of the anticline, from the point where the shales cross the Thayu Chaung northwards the shales continue regularly and can be traced in many exposures, but as has previously been pointed out, the topography is complicated and the shales do not form long valleys similar to those on the eastern flank. The dip varies from steep to vertical. In the north of the map however a long depression or valley marks the position of the shales (see section C.-C.).

Subdivision 5.—The sandstones of this subdivision touch the Thayu Chaung about 3,500 feet west-south-west of Ngahlaingdwin. Although they seem to dip gently south, they show irregularity of structure and sharp bends.

Since it seemed possible that these irregularities might turn out to be of importance and might seriously modify our views of the value of the anticline, we investigated the crestal area with particular attention. But we eventually came to the conclusion that the irregularities seen in the Thayu Chaung section are more or less local, and are followed to the north by a regular axial arch.

The ground rises gradually from this section in the Thayu Chaung, which is about 580 feet above sea-level, to heights of 752 feet, 840 feet (see trigonometrical points on map) and upwards, forming a distinct hill-range. The anticlinal axis follows the watershed. The crest (seen in sections of streams running east from the watershed) dips south at about 10°.

The arch is clearly seen ; to the east the dip increases to angles of 30° or 35° near the base of the Kinmungyon shales at a distance of between 2,300 feet and 3,000 feet from the crest ; westwards the strata dip more steeply, so that 800 feet from the crest the dip averages 50°.

The junction of the sandstones with the Kinmungyon shales is more clearly seen (owing to the topography) on the east than on the west.

In the Nwama Taung area, the sandstones of subdivisoin 5 are for a long tract markedly prominent over the strata of subdivision 4. In the Ngahlaingdwin anticline, the difference in hardness of the two subdivisions has little influence upon the orography; nevertheless a difference exists, thus at the point where subdivision 4 emerges upon the axis, and subdivision 5 forms two outcrops on either side of the anticline, the watershed follows the eastern outcrop of 5 and leaves the axis. It lies east of the trigonometrical point 890.

The two outcrops were seen in many cross sections and are always distinct.

Subdivision 4.—The axis from point 890 to the oil wells passes through this subdivision. The strata are thinly stratified shale and sand alternations, with occasional limestone bands. Shales are predominant in the Zaha Chaung section, while the sandstones are occasionally lignitic.

Subdivision 3.—The point where this subdivision emerges from the rising crest is interesting, owing to the indications of oil—the highest observed in this area.

This is illustrated by the sketch given below, scale 4 inches =1 mile.

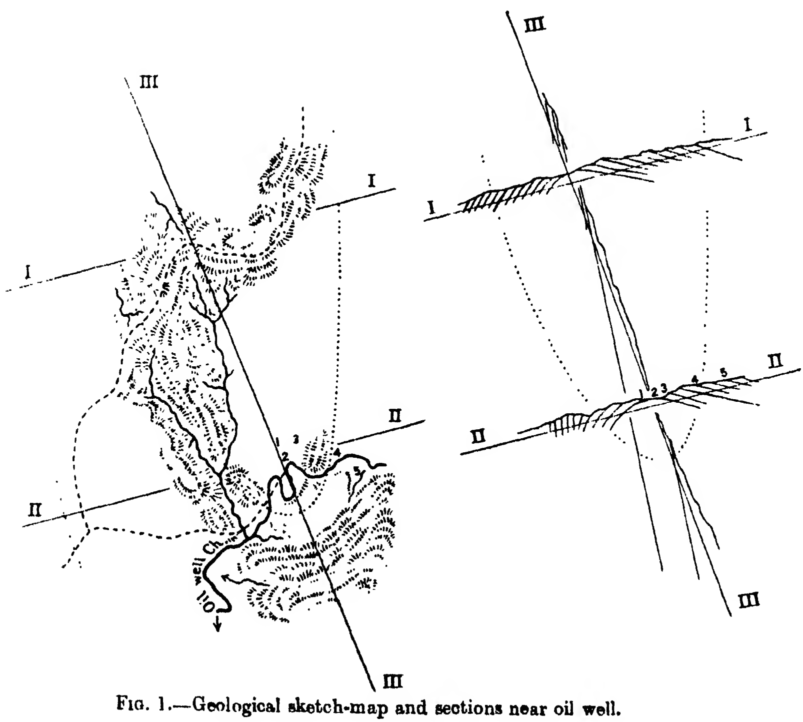


FIG. 1.—Geological sketch-map and sections near oil well.

Subdivision 3 may be defined as commencing by a bed of shale exposed in the oil wells stream east and west of the crest. The highest sandstones of this subdivision are seen south of the stream and contain foraminifera. They dip south at about 10°. The outcrops of this sandstone bed form small ridges on both sides of the crest. There is no marked lithological boundary between the two sub-divisions and the sandstones above mentioned have been included in sub-division 3 owing to the presence of foraminifera.

The oil wells stream gives a very clear section through the anticline. It is needless to describe it in detail, since the dip of the rocks is clearly marked on the map and sections (Plates 25, 26).

The oil seepage and the hand-dug wells.

South of pits 1, 2, 3, is a bed of oil-stained sandstone and a pool of water covered with a scum of brown oil. The bed dips to the south.

There are five pits or hand-dug wells, marked 1, 2, 3, 4, 5, on the map, No. 1 is 36 feet deep. From it 4 gallons are said to have been obtained in 19 days. There is abundant gas. The strata (sandy shale) dip to 25° west of south at 3° or 4°.

No. 2 showed only water and a smell of gas.

No. 3, 15 feet deep, smelt of gas.

No. 4, 21 feet deep, contained water and some gas.

No. 5 is 45 feet deep and contained water with an iridescent film of oil. Some bottles of oil were said to have been extracted.

Pits 1, 2, 3, are on the crest and below the highest sandstones of subdivision 3. No. 4 is dug in sub-division 4 and probably fails to reach the highest sandstones of sub-division 3. No. 5 is entirely in subdivision 4, and on the eastern flank.

It follows that the oil does not come from exactly the same horizon in each well.

Continuation of notes on subdivision 3.

The sandstones of this subdivision are very characteristic, owing to their red and yellow hue and rough unevenly weathered surfaces. Foraminifera are abundant. North of the oil wells is a bed of white crystalline limestone crowded with corals, this is about 3—6 feet thick. This coral reef forms a good horizon and can be followed for long distances. It was found at section D.-D. on the western flank.

The outcrops of subdivision 3 are clearly exposed and recognisable in the Zaha Chaung section (see section Plate 26). Here the sandstones contain bivalves and corals as well as foraminifera.

There is a striking difference in thickness of subdivision 3 in the two outcrops of this section, the western outcrop being nearly twice as thick.

There is a bed of *Velates*[1] in the western outcrop.

The dips of both these outcrops are steep.

North of the Zaha Chaung these two outcrops are easily followed and recognised by means of the beds of corals and foraminifera as far as the limits of our map (sections C.-C. and B.-B.).

Subdivision 2.—The upper boundary is vague, but I take the lowest nummulite-bearing bed as the base of subdivision 3. The top beds of subdivision 2 are alternate layers of shale and sandstone with lignite in thin layers. The strata on either side of the axis bend very sharply, but the bend is still unbroken and not faulted. Along the section D.-D. the dip on the east flank is from about 45° at the upper boundary of subdivision 2, to about 15° at the crest. On the west flank, the strata dip at 75° at the crest, and increase further west to vertical. There is an oil seepage here in the stream, which was hitherto unknown. In this section there is an abrupt change of dip at the crest, and lignite layers which are present on the east flank are not to be found on the west. It seems probable that a fold-fault is beginning here.

The oil seepage appears to be at a lower horizon in subdivision 2 than that found in the Nwama Taung section (see *ante* page 252). The structure becomes more complicated towards the north. In the Zaha Chaung section, there is no crest; the antlicine has become a crushed and faulted one. A section through the Zaha Chaung is shown on Plate 25. There is a striking want of correspondence between the succession of strata exposed on the east and on the west of the anticline, indicating faulting.

Proceeding up the Zaha Chaung, we find that after cutting across the centre of the anticline and reaching the western flank the stream in its upper portion traverses subdivision 3 and the top of 2 of which the top lignite layers are exposed here and there.

To the north another section (B.-B.) across the anticline shows the lignite layers of subdivision 2 exposed on either flank.

[1] This *Velates* is probably a variety of *V. schmiedeli* Chemnitz; the differences between it and the Cuise-la-Motte type are stated by Dr. F. Noetling, *Rec. Geol. Sur. Ind.* XXVII, p. 103. See also *Rec. Geol. Sur. Ind.*, XLI, p. 226. G. deP. C.

Subdivision 1.—In section B.-B. the topmost beds of subdivision 1 are just emerging in the centre of the anticline, which is here again an arch.

Owing to the increased intensity of folding, the anticlinal flanks are steeper and closer together. It is a well known fact that there often appears to be discordance, due to subsequent folding, between massive and thin-bedded strata (*e.g.*, between massive sandstones or limestones and shale). In such strata, the limestone or sandstone may show large bends, while the shales on the contrary are corrugated and contorted, and many slides are visible near the junction of the two. Perhaps then the arch of sandstones seen in the crestal exposure of subdivision 1 may be continued southwards unbroken beneath the faulted and corrugated strata of subdivision 2. If this conjecture be correct, it would seem that this arch of the sandstones of subdivision 1 represents the ultimate stage of resistance of the arch to the continually increasing tangential folding forces, since north of the section B.-B. the arch ceases to exist.

The axis of this arch coincides with the watershed.

Immediately west of the watershed, along the section B.-B., at the source of a small stream (see map) is a water-hole in massive sandstone showing a film of oil, while the sandstone is impregnated with oil at the margin. Here was dug a well about 45 feet deep, which yielded water with an iridescent film of oil. Following down the stream westward, one observes thick, sandstone strata, dipping south-south-west. At about 60 yards distance from the first oil-show, the section shows beds of sandstones with frequent patches of oil-impregnated rock. The oil is very noticeable and the section of strata showing oil is over 15 yards in length. This section is succeeded to the west by the interbedded sandstones and shales of subdivision 2. The dip rapidly increases and becomes very steep at this horizon.

East of the watershed, the beds show a gentle dip to south-east, and here at the source of an easterly stream are pools of water with films of floating oil; further east is seen the overlying subdivision 2.

The oil-impregnated strata on the western flank were followed north-west along the strike, and at a distance of about 600 feet another exposure showing slight traces of oil was found.

The point on the crest where subdivision 1 emerges to the surface is interesting through the change in orography as a result of the greater hardness of its sandstones as compared with the more shaly subdivision 2. South of this point to the Zaha Chaung the watershed is low, but northwards it commences to rise and form higher and higher hills with steep slopes on either side.

A somewhat similar change in surface relief was observed at the point where subdivision 5 emerges on the anticlinal crest. Here the massive sandstones of subdivision 1 form the long and high range of hills (the Yeyodaung) which extends northwards outside of the limits of our map. Outcrops are exclusively of sandstone not unlike those of the Nwamataung (see *ante*). The highest hill examined is about 1,300 feet above sea level.[1] On its northern slope is found a stream running east, and a path leading to the village of Kongya. Here the section shows a continuous series of sandstones dipping steeply east, and two oil seepages very close to one another. The sandstones are more or less massive, but especially so in their upper strata exposed on the east which are steeply dipping to the east and form a waterfall many feet in height. This locality is some 100 feet distant from the oil seepages, and also marks the top of subdivision 1. To the east, I found the lignites of subdivision 2 and the foraminiferal sandstones of subdivision 3.

To the west of the oil seepage the section shows vertically dipping sandstones, and it is certain that there is no anticlinal arch.

Summary.

From north to south the features of this anticline may now be summarised as follows :—

Subdivision 1, consisting of massive sandstones forms a high hill-range; the structure being a crushed anticline without an arch, except in the south end of the outcrop where an arch exists, and where there are important oil seepages.

Subdivision 2 shows no anticlinal arch, the rocks being crushed and broken at the centre of the fold. The anticlinal axis sinks steadily, and the tectonic disturbance is less intense. There is an oil seepage in this subdivision.

[1] Perhaps this hill is to be identified with the trigonometrical point 1213 of the Survey of India map, sheet 84 L. 5. C. Porro.

At the point where the outcrop sinks on the line of axis, there is an unbroken anticlinal arch. The asymmetry of the fold is remarkable, the dips being very steep on the west.

In subdivision 3 the anticline still sinks regularly and is noticeably asymmetric. At its top is an oil seepage and the Burmese hand-dug wells.

The sinking of the anticline continues steadily southwards, the angle being 10°—11°. The asymmetry is evident, but less noticeable owing to the increase in amplitude of the arch.

South of the Thayu Chaung the anticlinal fold diminishes and commences to die out in the sandstones at the base of subdivision 7. From the section B.-B. to this point the anticline has sunk not less than 6,000 feet.

It is to be observed that north of the Burmese hand-dug wells the anticlinal crest runs to north, 16° west, and that south of this point it gradually curves to an almost north—south direction. Thus it approaches the Nwamataung hill-range while sinking. South of the area shown in our map it is probable that the anticline changes to a terrace structure or belt of gentle or horizontal dips forming a simple flexure in the easterly dipping beds seen from the Nwamataung eastwards in such parts of the country to the south as have been examined.[1]

The relationships of the orography to the geology are also clear. The hill-range in the north sinks with subdivision 1 (massive sandstones). On both sides longitudinal valleys are found corresponding with the outcrops of subdivisions 2 and 3. The upper portion of the Zaha Chaung follows the outcrop of subdivision 3; thus it gradually approaches the axis and eventually cuts across the strike to join the Salin River in the east.

Two circumstances *viz.*, (1) the asymmetry of the anticline which is steeper on the west flank, and (2) the proximity of the Thayu Chaung explain the reason why the watershed does not coincide with the anticlinal axis, but has been shifted to the east. The asymmetry of the fold has brought about on the west an orographical relief showing steeper gradients. Subsequently a number of tributaries have cut back from the Thayu Chaung, and thus caused the displacement of the watershed. The asymmetrical anti-

[1] This conjecture is correct; the area to the south has now been completely mapped by the Geological Survey. G. deP. C.

cline of Yenangyat and others[1] show a similar but more marked orography.

These are the causes of the orographical difference on either side of the fold, of the number of cross streams on the west, and the continuous longitudinal depressions and ridges on the east (see *ante* page 256).

In subdivision 5 the watershed and anticlinal axis more or less coincide, because the more massive and resistant character of subdivision 5 balances the influence of the two circumstances mentioned above. In other words: the watershed was not displaced, because it consists of layers of more resistant character.

To the oil-prospector, the underground structure of the anticlinal arch, and the question whether owing to the asymmetry the underground arches may lie east of the surface arch, is a consideration of great importance. The axes of the subterranean arches of strata of the Ngahlaingdwin fold, without doubt are shifted to the east of the surface axis. The amount of displacement is related to two factors, (1) the different dips of either flank, and (2) the reduction in thickness of the upturned strata on the steeply dipping flank.

In the Ngahlaingdwin anticline, the reduction in thickness of the vertical and steeply dipping strata of the west flank is an undoubted fact, which we have proved by our geological survey, and which can be approximately estimated at the surface. This reduction may perhaps be due more to the mutual shearing and sliding of strata over one another than to actual plastic compression. Thus for these reasons the amplitude of the anticlinal arch is subject to variation: when therefore we take into consideration both these factors, it must be admitted that we can construct sections only with a limited degree of approximation, which decreases as the depth increases.

These explanations will perhaps justify my sections as against those drawn after the method of Dr. E. H. Pascoe for determining the displacement of subterranean crests of asymmetric anticlines,[2] which method, if followed, would have led us to assume a greater amount of displacement to the east. Dr. Pascoe determines the "apex-locus" of the anticline as the bisectrix of the angles of dip

[1] Examples of this structure are found near Grozni, Russia. C. Porro.

[2] E. H. Pascoe:—Asymmetry of Yenangyat-Singu anticline, *Rec. Geol. Sur. Ind.* XXXIV, p. 253.

of both sides of the anticline, without considering the effect of any reduction of strata ; with all due respect and acknowledgment of his geological results in Burma, I cannot share his opinion on this matter.

As far as I know it is generally admitted that the orogenic movement which formed the mountain-chains of Burma running north—south, was propagated from east to west.[1]

Without discussing the cause of the orogenic movement, or examining the relationships of the former Gondwana continent and the Tethys, I also agree with both authors referred to in my footnote in postulating an east—west strain and movement.

Admitting this general supposition, we must conclude that the anticline of Ngahlaingdwin was folded by a stress from east to west, and where the asymmetry occurs, the strata of the west, reacting against this pressure, must have been forced into a vertical position by the eastern flank. Had the folding force been exerted with greater intensity, we should have expected an overslide to the west.

Here I must make a short digression and allude to a much more asymmetrical anticline,—I mean that of Yenangyat.

This anticline contrasts with that of Ngahlaingdwin, in that it has a very gently dipping western flank, but a steep, vertical or reversed eastern flank : along this steep eastern limb runs a great longitudinal dislocation leading to the west.[2]

As a consequence of my foregoing remarks, one must assume that in the case of this anticline also the eastern side has moved against the reacting western side, while partly sinking and undersliding it.[3]

Thus in the Ngahlaingdwin anticline there is a tendency to overfold, while at Yenangyat there is on the contrary a tendency to underfold and underslide, although the tangential forces were in both cases propagated from the same direction.

[1] See Suess. Antlitz der Erde, I, p. 768 ; E. H. Pascoe, *Mem. Geol. Sur. Ind.*, XL, pt. 1.—The Oil-fields of Burma.

[2] See G. deP. Cotter : The northern part of the Yenangyat Oilfield. *Rec. Geol. Sur. Ind.*, XXXVIII, p. 302.

[3] I surveyed the Yenangyat anticline in 1911, and my results confirmed the investigations of Mr. Cotter, excepting that I consider that the angle of inclination of the fold-fault with the horizontal is greater than Mr. Cotter supposed. C. Porro.

Questions relating to Oil.

It is superfluous to mention here such oil occurrences as are known to belong to the Pegu Series, and I merely wish to remark that in 1912 a deeper horizon of oil-bearing rock was found in beds of Khirthar (Lutetian) age.[1]

The locality is close to the village of Peinhnebin, Minbu district. An examination of the map and orography shows that the same horizon is probably continued to the north-north-west up to the Nwamadaung exposures in our area.

The localities where oil seepages have been found have already been described. To recapitulate, oil seepages have been found at the following horizons :—

(1) In subdivision 3 near its upper limit.

(2) In the upper part of the lignite-bearing subdivisions 2.

(3) In the upper part of the massive sandstones of subdivision 1, and also some 100 feet below this seepage.

Probably the horizon numbered (2) corresponds with that recorded by Mr. Cotter from Peinhnebin, where also coal strata occur. The oil from (3) would correspond then to a still deeper horizon, in fact the deepest yet found. Considering the above seepages, there is certainly not sufficient evidence of oil to *prove* the existence of continuous and important oil horizons, but one would be taking too pessimistic a view, if one did not contemplate the possibility that these important oil horizons exist and that there are chances of finding large accumulations of oil at points favoured by the structural conditions. Alternations of shale and sandstone bring about good conditions of storage.

Localities favourable for prospecting must be chosen on the anticlinal crest, in places where the anticline forms an arch, and where the oil can accumulate, on being forced up by water pressure from the anticlinal flanks.

The angle at which the anticline rises (10°—12°) is in my opinion not large enough to preclude the possibility of storage of oil along the axis. There are other cases of similar anticlines which are productive, *e.g.* the Coalinga fields in California.[2] There, one of the producing areas is a monocline with a moderate angle of dip.

[1] G. deP. Cotter: The Pegu-Eocene Succession in the Minbu district near Ngape. *Rec. Geol. Sur. Ind.*, XLI, p. 230.

[2] See Bulletin 357 and 398, United States Geol. Survey.

If the anticline is to be tested, the following points should be taken into consideration.

At section B.—B. there is an anticlinal arch in the sandstones of sub-division 1, and good oil seepages. 300 feet on either side of the axis, the strata dip steeply, the westerly flank being the steeper; the arch is consequently narrow.

Wells might also be drilled along the axis from section B.—B. towards the north and towards the south. Towards the north one should drill to test the horizon from which seepages were observed in section A.—A., and one should extend operations from section B.—B. towards the north as far as the anticlinal arch exists: we know that this arch does not reach section A.—A. An unfavourable point is the absence of shaly beds between the sandstones. Transversely the drilling area is very narrow and practically coincident with the crest of the anticline.

Towards the south, one should explore the oil observed in abundant seepages in section B.—B. I have already explained the possibility (see *ante*) that the arch may be continued intact underground southwards from section B.—B. under the disturbed and crushed strata of the overlying subdivision. One should not, however, on the basis of my purely theoretical suggestion, risk a well too far south of B.—B. in the crushed area, but if the wells to the north were to prove successful, this theory might be corroborated by a gradual extension of wells southwards.

A surface arch is again seen near section D.—D. and this is continuous to the south. At section D.—D. itself there is a slight fault and a seepage. Here, even if the arch exists, it is too compressed and irregular to present favourable conditions of structure.

Between sections D.—D. and E.—E. the anticlinal arch bends at a short distance east of the axis at 45° and then increases to 60° of dip. On the west the dip increases rapidly to the vertical. Tests may be made very close to the axis and a little to the east of it. Thus there might be some hope of striking the horizon from which seepages were observed along section D.—D.

At section E.—E. subdivision 3, which is oil-bearing at its top, crops out on the axis. For the shape of the arch see sketch on page 258. It would be practically impossible to reach subdivision 1 and the oil connected with it, but the oil horizon of subdivision 2 could be reached at a depth of approximately 800 feet at the axis and at a greater depth on the eastern flank.

South of section E.—E. the oil of the horizon of the hand-dug wells would give a good objective for drilling down to. This might be tested both along the axis and on its eastern flank. Its depth of course increases to the south owing to the sinking of the anticline.

Briefly, oil-bearing strata may be expected at a reasonable depth, but the narrowness of the arch makes the location of wells difficult since one cannot be certain of striking the underground arch accurately.

One must not lose sight of the underground transgression of the anticline arches to the east.

From the section G.—G. southwards, the structural conditions of the anticlinal arch are better, since the arch increases gradually in width and the strata east of the axis do not dip steeply. On the other hand the oil-bearing horizon is at a greater depth, and with the depth increases the uncertainty regarding the structure, and the position of the subterranean axis. We must not, however, leave out of consideration the possibility that higher oil-sands may exist although no seepages were found. We know that oil in paying quantities is found in the Pegu Series.

APPENDIX.

By G. deP. Cotter.

Dr. Porro has asked me to write a note upon the age of the rocks at Ngahlaingdwin. This task has become an easy one owing to the advances in mapping made by the Geological Survey since Dr. Porro's visit to this field in 1912. In spite of the hopes at one time entertained of the prospects of this area as an oil-field, it has not yet been tested. The poor results obtained from the Minbu field, which is a narrow anticline like that of Ngahlaingdwin, and the distance of the Ngahlaingdwin anticline from the river, make the testing of it a costly and highly speculative undertaking.

The seventh subdivision of Dr. Porro contains a fauna described in considerable detail by Dr. F. Noetling (*Pal. Ind.*, New Ser., I (3). Fauna of the Miocene Beds of Burma). There is no doubt as to its approximate correlation with both the Gaj beds of India and the Java beds, the fauna of which has been worked out by K. Martin.

In the uppermost part of this subdivision *Ostraea Verneuili, O. digitalina. O. crassissima, O. gingensis,* and *O. crassicostata,* have been found, while oysters are usually badly preserved and not identifiable in the lower part. Other species are *Vicarya callosa* Martin, *Venus aglaurae*, *Voluta dentata*, *Cypraea granti*, *Aricia humerosa*, etc. Foraminifera are usually absent and echinoids are rare.

Dr. Noetling regarded this fauna as of Miocene age. This is probably as close an approximation as we can get at present.

Underneath this stage lie the shales and clays of Dr. Porro's sixth subdivision. They are the same clays as those from which I collected specimens of *Lepidocyclina theobaldi* in the south of the Minbu district.

The specimens from this stage at Ngahlaingdwin are on the whole somewhat poorly preserved. Specimens of a *Lucina*, the same species as that which L. V. Dalton identified as *L. globulosa* Desh. (*Q. J. G. S.*, LXIV, page 604) and which is unquestionably closely allied, although perhaps not identical with, the Italian species, have been collected. Other molluscs appear for the most part to range upwards into the stage above. The foraminifera are of help in determining the age in south Minbu. *Lepidocyclina theobaldi* is the same species as is found in the Nari of India, and is probably identical with *L. elephantina* Tourn. There are also present some sub-microscopical nummulites and a large *Heterostegina* with which is associated a smaller megaspheric form (see *Rec. Geol. Surv. Ind.*, XLI, page 231, Plate 20, fig. 1).

If we accept the views of H. Douvillé and J. Boussac regarding the range of the Orbitoides and Nummulites, we should probably place these shales in the Chattian stage. These clays and shales have been called the Padaung Clays.

Dr. Porro's sub-divisions 4 and 5 form one stage, which we have called the Shwezetaw Sandstones. They have yielded very few fossils in Ngahlaingdwin. In south Minbu at this horizon specimens of an *Ampullina*, which my colleague Mr. Vredenburg regards as identical with *A. crassatina*, have been found (*Rec. Geol. Surv.*, XLI, p. 226). Accompanying this are:—a species of *Vicarya* and a species of *Cardita*.

In the same stage is found a species of *Clypeaster*. In the Pakokku district, this stage is, as far as surveyed at present, represented by freshwater beds, which yield two species of *Cyrena*, one of which is very close to, if not actually identical with *C. borneensis* Bottger.

The fauna of this stage is so scanty, that if we do not take into consideration the fauna of the stages above and below, we should be quite uncertain of its age.

Dr. Porro's subdivisions 2 and 3 taken together form what we have called the Yaw Stage. This stage has yielded a large fauna which I am at present studying. Amongst other species may be mentioned *Orthophragmina sella* D'Arch., *Nummulites yawensis* Cotter, *Velates schmeideli* var. cf. description by F. Noetling in *Rec. Geol. Surv. Ind.*, XXVII, page 103, *Volutilithes sp. aff. ambigui* Sol., *Gosavia birmanica* Dalton, and many other characteristic species. These clearly indicate an Upper Eocene age.

Dr. Porro's subdivision 1 is equivalent to our Pondaung Sandstones. This stage has yielded few fossils,[1] but amongst those collected is a species of *Arca* allied to the Cretaceous form *Trigonoarca abrupta* Forbes.

Dr. Porro's map shows no rocks of older age than the Pondaung Sandstones. In the Yaw River section in the Pakokku district however, a full sequence has been worked out downwards from this horizon to the Upper Cretaceous.

Below the Pondaung Sandstones come the Tabyin Clays, which contain nummulites and the *Arca* which is so frequently found in the beds above. Below these are found in most sections another series of the sandstones which we have called the Tilin Sandstones; these also contain small nummulites.

Below these is a very thick series of shales with numerous bands of conglomerate at the base; this we call the Laungshe Shale. It contains *Operculina* and *Orthophragmina* and is probably basal Eocene in age. Below this I have found beds containing *Exogyra*, *Nerinaea*, *Trocalia*, and some Cretaceous-looking *Orbitoides* showing four central chambers. With the exception of the Yaw stage, the fauna has merely been glanced at and there remains a very large amount of palæontological work and description before we can fix the exact age of each stage.

In the above notes I have made a few allusions to the age of these various stages in terms of European nomenclature. But the Indian Empire probably possesses in its Burma, Baluchistan, Sind, and Kachh sections some of the finest sections of Tertiary rocks in the world; moreover the fauna is a tropical one rich in nummulites and other foraminifera. Indian geologists have, therefore, little need to enquire whether such and such a stage is to be correlated with the Latdorf beds or the beds at Ludes. We must work out our own sections with open minds on such doubtful questions as the occurrence of *Orthophragmina* in the Oligocene or of *Lepidocyclina* in the Eocene. I do not propose at present, therefore, to offer any opinion as to the correlation of the Burma Tertiaries with those of Europe.

EXPLANATION OF PLATES.

PLATE 25.—Section across map Plate 26.

PLATE 26.—Geology of the Country near Ngahlaingdwin.

[1] In December 1914 I discovered vertebrate remains (teeth, etc.), in rocks of this horizon. These include two new genera of *Anthracotheriidæ*, one Titanothere, and one *Metamynodon*; a description will shortly be published by my colleague Dr. Pilgrim and myself. G. deP. C.

NOTES ON THE GEOLOGY OF CHITRAL, GILGIT AND THE PAMIRS, BY H. H. HAYDEN, C.I.E., F.R.S., *Director, Geological Survey of India.* (With Plates 27 to 32.)

THESE notes are the outcome of observations made during a journey to Europe on leave through Chitral, Gilgit and the Pamirs between April and August, 1914. Owing to the conditions under which it was made, involving marches of from 10 to 40 miles daily with but rarely a complete day's halt, the journey constitutes only the barest geological reconnaissance, and the results are necessarily incomplete, disconnected, and often inconclusive; so much so that I should have hesitated to publish them were it not that they embody the only observations on the geology of Chitral, and perhaps also of the Pamirs, that are likely to be made for some time. They may also be of some assistance to future workers in those regions.

I have to express my indebtedness to all officials, British, Russian and Chinese, with whom I came in contact during my journey, for their unfailing courtesy and kindness. I am especially indebted to Monsieur C. Nabokoff, Imperial Russian Consul-General in India, whose energetic assistance was responsible for the generous treatment accorded to me in Russian territory and to Sir George Macartney, K.C.I.E., British Consul-General at Kashgar, for help in Chinese Turkestan and for innumerable acts of kindness and hospitality.

Previous observers: Chitral.

Chitral is best known for its orpiment mines, which have been described more than once,[1] but beyond this nothing was known of its geology until Major I. H. Grant in 1899 sent to the Geological Survey of India some Devonian[2] fossils collected at Showar Shur in the Yarkhun valley. Subsequently Captain (now Colonel) B. E. M. Gurdon obtained a further series of Devonian fossils from the hills opposite Reshun; they were described by the late Mr. W. H. Hudleston

[1] An interesting description of them will be found in Col. P. L. Kennion's fascinating book *Sport and Life in the Further Himalaya* (1910), p. 144.

[2] *Mem. Geol. Surv. India*, XXXVI, p. 31 (1904). The locality has hitherto been erroneously described as the Baroghil Pass; the actual locality lies in longitude 73°35′ and latitude 36°50′.

in the *Geological Magazine*,[1] and geological notes, made by Sir Henry McMahon, together with a discussion of the latter by General C. A. McMahon, were included in the same paper. It is a curious coincidence that the fossils collected in both cases were Devonian, although they were derived from localities more than a hundred miles apart. Those from Showar Shur, however, are regarded by Mr. Cowper Reed[2] as Lower, whereas those from Reshun are Upper, Devonian.

The presence among the Chitral fossils of specimens of *Spirifer Verneuili* var. *Archiaci* Murch. identical with forms collected by me in Afghanistan some years ago,[3] led to the hope that the stratigraphical conditions in Chitral might perhaps combine features both of the Afghan and of the Himalayan province. On the one side, the western, the most characteristic among the few stratigraphical features known are the presence of a well developed Devonian fauna, a great thickness of Fusulina limestone and a littoral and shallow-water facies of the Trias-Jura. The Himalaya, on the other hand, are characterised by the general absence of Devonian fossils, the absence of Fusulina limestone, and the presence of a very finely developed deeper-water facies of the Trias.

Route followed.

My journey through Chitral and the Pamirs was undertaken with a view to elucidating the relationship between the above stratigraphical provinces. The route followed lay from Dargai *viá* the Malakand, through Swat and Dir, over the Laorai pass to Drosh and Chitral; thence up the Mastuj river *viá* Reshun to Mastuj, and up the Yarkhun river to the Baroghil and Shawitakh passes on the frontier of Wakhan. From Yarkhun I crossed the Darkot pass into Yasin, thence *viá* Gupis to Gilgit and Hunza, and over the Mintaka pass to the Taghdumbash Pamir and Tashkurghan. From Tashkurghan I followed Stoliczka's route over the Nezatash (Shakhlakh) pass to Aktash, thence through the Great and Alichur Pamirs to Murghabi and along the Ak Baital and Muskol rivers to Great Kara-kul; then eastward over the Kiziljiyiq pass to Rang-kul and finally out by the Haramut (Aramuth) pass to Muji in Chinese Turkestan and over the Ulug-art to Kashgar. The distance thus covered was about 1,300 miles, and as the time occupied was only 125 days, the opportunities for

[1] Decade IV, Vol. IX, pp. 3-8, 49-58, January and February 1902.
[2] *Rec., Geol. Surv. India*, XLI, 86 (1912).
[3] F. R. Cowper Reed: *Rec., Geol. Surv. India*, XLI, 105 (1912). H. H. Hayden: *Mem., Geol. Surv. India*, XXXIX, pt. 1 (1912).

mapping were extremely small, and the map published with this paper is, therefore, merely diagrammatic and is intended to show only the general distribution of the broad stratigraphical divisions.

Previous observers : Gilgit.

With regard to Gilgit, petrographical notes by Professor T. G. Bonney and Miss C. A. Raisin on specimens collected by Sir Martin Conway were published in the latter's "Climbing and Exploration in the Karakoram-Himalayas."[1] Captain (now Sir Henry) McMahon and Captain (now Sir James) Roberts also made collections of rocks in Yasin and Gilgit and notes on them were published in the *Quarterly Journal* of the Geological Society[2] by the late General McMahon in the year 1900. General McMahon correlated the limestones of Gilgit with the Carbo-Triassic series of Kashmir and the North-Western Himalaya, and the underlying schists he attributed to either the Lower Carboniferous or the Silurian system.

Previous observers : The Pamirs.

Until last year we were dependent for practically the whole of our knowledge of the geology of the Pamirs on the work of Stoliczka, who travelled from Yangi Hissar near Yarkand through Tashkurghan and the Little Pamir to Kala Panja on the Oxus, returning by the Great Pamir and Istik.[3] He described the greater part of the country as consisting of slate, conglomerate and gneiss, with thick masses of limestone at Nezatash, Aktash and Istik. In the limestones he found Upper Triassic fossils between Nezatash and Aktash and crinoids at Istik. He regarded the Istik limestones as Carboniferous. Further geological observations are to be found in the writings of D. L. Ivanow, a Russian mining engineer, who travelled in the Pamirs about ten years after Stoliczka.[4] The petrographical and stratigraphical observations are not given in great detail in the only paper by that author which was accessible to me, but it contains much valuable information on the tectonic aspects of the Pamirs. Ivanow was, in fact, the first to ap-

[1] Maps and Scientific Reports (1894).

[2] Vol. LVI (1900), p. 337-368.

[3] *Scientific Results of the Second Yarkand Mission*, Geology ; by W. T. Blanford, 1878.

[4] " A short report on geological investigations in the Pamirs." *Trans. Russ. Imp. Min. Soc.*, ser. II, Vol. XXII, p. 255 (1886). See also " Notes on fossils collected by Messrs. Regel, Smirnow, Severtsow, Ivanow and von Schultz " by G. D. Romanowski ; *id.*, Vol. XIX, p. 1 (1884).

The original papers are in Russian and I am greatly indebted to Monsieur P. A. Rogalski of the Imperial Russian Consulate General in Calcutta for his kindness in getting them translated for me.

preciate the true structure of the Pamirs and to realise that they consist of a parallel series of equatorial mountain ranges, and he showed conclusively that none of the ranges was, as had formerly been claimed by Semenow, meridional. He observed that the trend-lines were north-easterly on the western side of the Pamir, almost equatorial through the Pamirs, and south-easterly on the east. His observations have been entirely borne out by such further examination as I have been able to make. At the same time he did not neglect the purely geological aspect. He describes the Pamirs as an immense massif, with a granitic and gneissose core. He points out that the granite has intruded into and metamorphosed sedimentary rocks, which he records as prevailing in the northern part of the Pamirs and which he refers to slate, dolomite, limestone and arkose. He also mentions oolitic limestones, which he refers to the Devonian system. He records the presence of rock-salt near Rang-kul ; and infers from information obtained from a guide that the depression constituting the Baroghil pass between Chitral and Wakhan is due to the presence of gypsum ; he further makes an ingenious suggestion that the name of the pass should not be Baroghil but Bor-agyl, *i.e.*, the pass of gypsum.[1] The guide's information has now proved to be incorrect, as I examined the Baroghil pass carefully and found no signs of gypsum there. The depression itself is, in fact, an old glacial valley.

Maps.

I have already pointed out that the geological map published with this paper is only diagrammatic and aims merely at separating the broad stratigraphical divisions. Even so, boundary lines are only approximate ; nor, indeed, could they be more, since the topographical maps which were available to me are far from accurate. Circumstances made it impossible for me to obtain Russian topographical maps in time, and I was dependent on such maps as had been published in England and India. I had also with me a map recently published in *Petermanns Mittheilungen*[2] by Dr. Arved von Schultz and said to be based on Russian maps on a scale of 1 : 420,000, "with further additions from the newest sources and from the author's own observations." I found, however, that in most respects this map was inferior to those published in India more than 20 years ago and marked no advance on Lord Curzon's map ; even in those

[1] See also Suess : *The Face of the Earth, III*, 298.
[2] Vol. 58, 190-193, 261-265 (1912).

parts of the Pamirs that the author claims to have visited himself, the map frequently proved to be inaccurate. I have, therefore, inserted the geological observations on the most recent map published by the Survey of India on a scale of 1″=32 miles.

I.—Swat, Dir and Chitral.

Igneous and metamorphic zone.

The outer hills from Dargai through Swat consist chiefly of dark hornblendic rocks, with much intrusive granite, and occasionally slate and dolomitic limestone. Between Dargai and the Malakand, the rock is chiefly hornblende-schist, much foliated and crushed, and full of quartz veins. Below the Malakand, on the road to Chakdara, the hornblendic rocks are replaced by granite. To the north of Chakdara, the hills consist of gneiss and schist, the foliation planes of which dip approximately to the north-east. To the south of Chakdara, the dip swings round to the east.

At about 9 miles from Chakdara, on the road to Sarai, beds of grey and yellowish-white crystalline limestone are interbedded with quartzose and hornblendic schists, associated with a certain amount of foliated granite. The metamorphic beds appear to be of sedimentary origin and recall the metamorphic series of the Jagdallak ruby mines. The limestones, however, do not contain any accessory minerals. From Sarai northwards, the road runs through an alluvial valley for some distance, subsequently rising on to the rocky hills on the north side of the valley; before leaving the plain, it crosses a small stream, which has cut through a hard layer of compact grey nodular *kankar*.

The hills consist of the usual hornblendic schists, with a good deal of foliated granite and here and there some eurite. The schists are usually hornblendic, but occasionally contain siliceous bands resembling fine-grained quartzite. Near Sado, bands of coarse amphibolite are common.

From Sado northwards, the road follows the left bank of the Panjkora river. The prevailing rocks are still hornblendic, but are usually gneiss rather than schist. A thick band of hard dark-grey crystalline limestone is seen for some way along the road above Sado. Beyond this, the schists and gneisses are replaced by quartz-diorites resembling gabbro in appearance; the ferro-magnesian mineral, however, is a fresh dark-green ophitic hornblende.

The felspars, which are considerably kaolinised, include albite and microcline with some labradorite; chlorite and epidote are also present; the hornblende is probably secondary and derived from a pyroxene. The diorite is penetrated by numerous veins of coarse pegmatite, consisting of felspar and hornblende with some quartz. Coarse basic bands, consisting almost entirely of large crystals of hornblende, and similar to the rock already recorded to the south of Sado, are fairly common.

The above igneous rocks continue the whole way to Rabat, and appear to form all the ranges on either side of the river. This Panjkora igneous mass is clearly intrusive in, and responsible for the metamorphism of, the schist series. To the north of Rabat, along the river, the same coarse diorites continue, with basic pegmatites and great masses of amphibolite, which is often very coarse and which at first sight looks like a coarse diallage rock. The series is interrupted here and there by comparatively insignificant patches of hornblendic schist, relics no doubt of the metamorphosed sedimentary series already referred to. At about three miles south of the Levy post of Warai, the basic series is pierced by occasional veins of eurite, which increase in number northwards and subsequently pass into a coarse biotite-granite. The change in the nature of the rock is reflected in the topography, and the steep, dark, rugged hills of the basic series are replaced by rolling hummocky country with a white sandy surface. This belt of granite is only about 3 miles wide, and gives place at about a mile above Warai to schists and gneisses full of granite veins. In places the rock looks almost like phyllite, but is always black and hornblendic. Similar rocks (amphibolite and hornblende gneiss) continue northwards for some miles, penetrated everywhere by granite veins. The dip of foliation of the schists is usually high to WNW. Occasionally, however, it is quite low, almost horizontal. The strike is almost always ENE or NE by E. Near Darora Levy post, granite comes in again and extends northwards for a considerable distance. It is subsequently replaced by schistose and gneissose beds, which, near the junction of the Panjkora and Baraol rivers, become hard and dark and very compact, gradually passing into quartzite at Chutiatan bridge. Slates soon make their appearance, and quartzite and slate (chiefly the latter) continue all the way to Dir. The strike is approximately E-W, with a variable dip usually northerly and sometimes very

Granite at Warai.

steep. The slates approach phyllite, and the series recalls parts of the Purana group of the Himalaya.

Granite of Dir and the Laorai Pass.

A short distance above Dir the slate and quartzite series gradually becomes more highly metamorphosed, finally becoming gneissose. About a mile above Panakot the sedimentary series is replaced by a medium-grained granite, two spurs of which run down from the hills on either side and almost close the valley. This granite continues all the way to Gujar at the southern foot of the Laorai pass. Between Gujar and Ziarat, the whole country was under deep snow when I passed through, but, to judge from such rock as could be seen, the Laorai pass and surrounding hills are composed of granite and gneiss, the latter prevailing on the northern side. The gneiss is granitic and dioritic, and often rather basic. Below Ziarat it becomes fine-grained, resembling quartzite, and is associated with mica-schists, which at half a mile above Ashreth are replaced by a thick bed of crystalline limestone with slate. The latter beds are almost vertical, dipping to the north-west at about 85°. Further down the valley, below Ashreth, the limestone is followed by slate, phyllite and schistose grit, succeeded by quartzite and slate, the latter rocks sometimes bright red. The whole of this latter series bears a striking resemblance to the rocks seen at the mouth of the Ghorband valley in Afghanistan and believed to be Lower Palæozoic. The structure is complicated by considerable folding and probably also by faulting.

Ashreth limestone and slate.

Volcanic agglomerate of Mirkani ;

About ¾ mile below Ashreth, a large block of sheared conglomerate is seen lying by the roadside. It is not *in situ*, but the same rock is found a little further on, on the hill-side above the road, and forms the greater part of the high hill to the south of Mirkani post. The series in which this conglomerate occurs is here 800 or 1,000 feet thick. The lower beds consist of a true agglomeratic slate composed almost entirely of fragments, rolled boulders and huge angular blocks, of volcanic rocks. Higher up it becomes gradually finer, passing into a slaty conglomerate and finally into a grit. Both above and below, this agglomerate series is cut off at Mirkani by an intrusive granitic rock, consisting of quartz, felspar, chlorite and epidote. The quartz contains many inclusions, but under the microscope appears very fresh

Granite intrusive in it.

and clear in comparison with the felspar which has been almost completely changed into secondary products. The felspar is usually idiomorphic, but its extreme state of alteration makes it impossible to determine its species with any certainty. It appears, however, to have been orthoclase for the greater part, with, perhaps, some albite. Chlorite is common throughout the rock, and may be an alteration product of mica. Both above and below the agglomerate series, this igneous rock lies in apparent parallelism with it, but schistose beds occur in both cases at the junction and the upper grits have been converted near the boundary into a gneissose schist. No apophyses were observed running from the igneous mass into the agglomerate, but, in spite of this, the rock must be intrusive. It is certainly intrusive into a schistose sedimentary series, apparently older than the agglomerate, exposed at Mirkani post.

Two conglomerates between Mirkani and Drosh.

Up to this point, from the Malakand to Mirkani, the road to Chitral has run across the strike of the rocks. At Mirkani it turns and follows the Chitral river, which up to Drosh runs almost parallel with the strike. On the way to Drosh, however, a few higher beds are seen. A good section is found at Badurgal, where the agglomerate series, greatly crushed, is seen striking NE-SW, and dipping at 65° to NW. The rock has been cleaved to such an extent that the original bedding has been completely obliterated and can only be traced by means of the pebble bands. Where these are not present, one is very liable to mistake cleavage for bedding. At Badurgal the agglomerate series passes up into slate, and a little farther along the road to Drosh numerous blocks of quite a different conglomerate are found lying by the road-side, having evidently fallen from the cliffs above the road. The latter conglomerate, which is also sheared and slaty, is composed for the greater part of small pebbles of limestone, but contains also some granite and trap. The rock is extremely like a conglomerate, to be subsequently referred to, which is found at Reshun (p. 284).

Volcanic series between Mirkani and Drosh.

About 1½ mile above Badurgal the Mirkani agglomerate series passes up into a bed of trap, which is followed by a great thickness of conglomerate and volcanic breccia with occasional trap-flows, but by far the greater part of the series is either breccia or conglomerate. The fragments of which the latter rocks are composed are usually angular and consist of trap. The road runs along the volcanic rocks for some miles, skirting the river along the left bank.

At about two miles below Drosh the trap suddenly gives place to slaty beds again. Among these, about 30 feet above the road, there is a large outcrop of a finely laminated limestone full of fragments of comminuted foraminifera. I took this at first for a crushed Fusulina limestone; examination with a pocket lens, however, showed that the long narrow sections were not *Fusulinæ*, and I referred them provisionally to a *Bryozoon*. It was not till I returned to Calcutta and was able to examine slices of the rock under the microscope that I discovered that the supposed *Bryozoa* were fragments of *Orbitolina*. The rock has been so crushed that the foraminifera have been broken into small fragments and I have not found any complete specimens. There is no doubt, however, that the fragments belong to *Orbitolina*, as I have found similar fragments in a shale containing undoubted *Orbitolina* and associated in Yasin with a bed containing hippurites. The latter rocks lie unconformably on a trap series, which is almost certainly the Panjal Trap, and which I am inclined to regard as equivalent to the trap of the Drosh-Mirkani section.

Orbitolina Limestone.

On the left side of the river, there is an ascending sequence from the Ashreth limestone, through the agglomerate, up to the top of the Trap series. Along this bank the prevailing dip is north-westerly and the volcanic series appears to extend across the river high up into the hills on the opposite bank; a bed of brilliantly white rock which caps those hills was subsequently found to be crystalline limestone and to be separated from the volcanic series by a belt of gneiss. If I had known at the time the real nature of the Orbitolina limestone, I should have spent some time at Drosh and examined the section thoroughly, but the general resemblance of the volcanic series to the Panjal Trap, and the presence of the supposed bryozoan limestone associated with it seemed to fall in with the assumption of a steadily ascending sequence, for the dip on the right bank of the river was quite clear and seemed to be everywhere north-westerly also. The subsequent discovery that the latter part of the section comprised the metamorphic rocks above referred to did not necessarily preclude the straightforward interpretation of the sequence, although it certainly introduced an element of doubt and suggested the possibility of a fault along the valley. The evidence of disturbance, which is considerable on the left bank of the river, taken together with the apparent position and schistose character of

Relation of Orbitolina Limestone to volcanic series.

the Orbitolina Limestone, lends further support to the idea that an important fault runs along this valley and its structural continuation the Shishi valley. I do not know the exact relationship of the Orbitolina Limestone to the volcanic series, but where I saw it on the hillside, it appeared to overlie the latter. The conditions, however, are complicated by local disturbance and there is some doubt as to whether the apparent sequence is the true one ; a persistent snow-storm during my examination of the outcrop added still further to the confusion, but in view of the section subsequently found in Yasin, the most plausible view is that the limestone overlies the volcanic series unconformably and that the latter is the equivalent of the Panjal Trap. A little way beyond the limestone, but separated from it by an outcrop of trap, I noticed on the roadside a cliff of schistose, much crushed quartzite which appeared to dip into the hill, that is to say, in the opposite direction to the prevailing dip.

Tertiary sandstone of Drosh and the Shishi river.

Before describing the rocks met with above Drosh, it will be well to refer to a much younger deposit observed for the first time in the valley of the Chitral river some miles lower down. This is a coarse sandstone, often containing pebbles, which is first seen at the stream above Galatak and thence continues all the way to Drosh. It is a coarse grit or sandstone with bands of conglomerate, and is seen at intervals on the hill-sides above the river running up to 80 feet or more above the present river bed. It is false-bedded and clearly of fresh-water origin, and exactly resembles typical upper Siwalik deposits. It dips inwards slightly towards the hills, and recent river deposits lie on it unconformably at Drosh, where it underlies the fan on which the village stands. Similar deposits, presumably of younger Tertiary age, are seen at the junction of the Shishi and Chitral rivers, where they include also yellow and lavender clays. They are found also up the valley of the Chitral river, towards Chitral, sometimes as much as 500 feet above the present river-bed, though they have been to a great extent removed in recent times by denudation.

Disturbed rocks of the Shishi valley.

A short distance above Drosh the Shishi valley joins that of the Chitral river. The former valley is the structural continuation of the valley of the Chitral river between Drosh and the Afghan frontier. Above the junction of the two streams the Chitral river cuts across the strike of the rocks. For the first few miles of the road from Drosh to Gahiret the section is not clear, since the solid geology is hidden by a broad fan. A short distance below the point at which the Shishi stream enters the Chitral river, rock again crops out on the road-side; this consists of trap, some schistose beds (possibly ash), and thin beds of a grey limestone with thicker bands of cream-coloured crystalline limestone. The beds dip steeply to WNW, and are underlain by the Trap series along the road up to the bridge over the Shishi stream. About a quarter of a mile up the stream above the bridge, two bands of dark-grey semi-crystalline lime stone with streaks of calcite crop out on either side of the valley. The strike is approximately NNE-SSW, and the dip very high to WNW. One of the outcrops of limestone forms an anticlinal saddle standing on end, *i.e.*, pitching vertically. This outcrop occurs on the left bank and appears to be represented on the right bank by masses of broken and crushed rock showing no particular strike or dip. The other outcrop occurs on both banks and forms a great vertical wall about 400 feet high on the right bank. All these beds are overlain unconformably by the younger—supposed Siwalik—sands and clays.

Granite and gneiss between Drosh and Gahiret.

A little way above the Shishi bridge on the road to Gahiret, the path mounts to the face of a cliff overhanging the river, and is cut out of a dark fine-grained biotite gneiss. The latter is much folded and crushed; under the microscope the component minerals are all found to be broken up into small fragments. The rock contains veins of pegmatite, with felspar predominating, which share in the foliation and crumpling of the gneiss. There are also infiltration veins of quartz and reddish-brown calcite, which cut across the foliation.

Crystalline limestone of Gahiret.

The belt of gneiss is some miles wide and is eventually replaced between Kes and Gahiret by a thick band of grey and white crystalline limestone. This is the bed already referred to as seen running along the hill-tops on the right bank of the river opposite Drosh. It dips steeply (60°—70°) to NW and crosses the river below Gahiret, making a marked bluff on either side of the river. From this point on to about half a mile above Gahiret the rocks are almost entirely calcareous. The crystalline limestone is overlain by a schistose rock, composed of fragments of slate and limestone, which is succeeded by a thick mass of grey crystalline limestone less highly metamorphosed than the rock at the base of the series. Just before reaching Gahiret, the road is carried on a gallery along the face of a cliff of this limestone, which is here dark-grey with light veins and masses of yellowish calcite.

Slate series of Chitral.

The total thickness of the calcareous series appears to be very considerable, probably between 2,000 and 3,000 feet. About half a mile above Gahiret, on the right bank of the river, the limestone gives place to schistose slate (phyllite). Some calcareous beds are associated with the slate but the series subsequently becomes one of slate, chiefly with some quartzite. The latter rock is seen on the right bank of the river just below Urghuch. A little further on, at about the 22nd mile, where the road ascends and crosses a cliff, a fine-grained diorite is intrusive in the slate and quartzite.

Relation of crystalline zone to volcanic series.

The relationship of the gneiss series to the trap and Orbitolina limestone of Drosh is obscure. The covering of Siwalik and younger beds leaves only patches of the older rocks visible here and there, and no continuous section is to be seen along the road. I have no doubt that clear sections could be found higher up the Shishi valley, but as the chief object of my journey lay in the Pamirs, I hesitated to deviate from the main road through Chitral. The rocks at the mouth of the Shishi valley are so disturbed as to give little clue to the true sequence. The gneiss also has been intensely folded, and its relationship to the Trap series is not clear ; I think, however, that it represents an intrusive granite. The true relationship could no doubt be ascertained on the fine section exposed in the hills on the right bank of the Chitral river opposite Drosh, which I had not time to visit.

Metamorphic rocks between Chitral and Reshun.

From Chitral to Koghazi on the Mastuj river the road to Mastuj lies on the slate and quartzite series, which is intensely folded and faulted and in numerous places contains bands of an intrusive dioritic rock. Just beyond Koghazi, the crystalline limestone, which has hitherto been conspicuous high up on the hills on the left bank of the river, comes down to the road where the stream from Golen joins the Mastuj river. It is completely crystalline, and forms enormous cliffs sometimes with a sheer face of a thousand feet or more. The Golen stream has cut a deep and narrow gorge through the limestone, which, some little way up the stream and at a short distance below the small village of Golen, abuts against granite, which latter appears to form the higher hills at the head of the valley.

Above the Golen stream the limestone again draws away from the river which runs through slate almost all the way from Reshun, the limestone being higher up in the hills on the left bank. Opposite Baranas the lower slopes on the right bank of the Mastuj river appear, from the opposite bank, to consist of dark slates with reddish bands passing up into a great thickness of a brown rock forming very thick beds. A few miles below Reshun, where the Owir valley debouches into the main valley, this brown rock comes down to the road. The underlying slates are hard, dark, often quartzose, and are overlain by a dark conglomerate of quartzite pebbles in a coarse slaty matrix. This passes up into brown sandstone and grit followed by a thin bed (2 feet thick) of intensely black carbonaceous shale. Over this again is more grit and sandstone, the grit having strings of pebbles in it and passing into a conglomerate.

The Reshun section.

In the valley behind Reshun there is a good section of this series. About 4 miles up the valley the slate series is overlain by the conglomerate. The latter must be at least 1,500 feet thick (Pl. 28 fig. 1). It passes up into a thick series of red shale several hundred feet thick. This is overlain by quartzite, followed by hard compact limestone, which at Reshun village contains sections of large brachiopods, but the limestone is so hard that no fossils can be extracted; the rock merely splits up into rhomboidal fragments.

Conglomerate in valley behind Reshun.

Higher up the Yarkhun river, opposite Shugram and also in the high hill behind that village on the right bank of the river, the hard Reshun limestone is overlain by siliceous limestone and quartzite. The limestone often contains crinoids. On the very top of the high hill behind Shugram, this is overlain by limestone containing a fairly large fauna, comprising chiefly corals and brachiopods. These are the beds, and this is probably the locality, from which Colonel Gurdon's fossils described by the late Mr. Hudleston[1] were derived. As already stated, their age is Upper Devonian. Hence the underlying quartzites and siliceous limestones presumably represent the lower part of that system and probably part at least of the remaining older Palæozoic

Devonian system.

[1] *Geol. Mag.*, Decade IV, Vol. IX, pp. 3-8, 49-58. January and February, 1902.

systems. In the absence of fossil horizons it is impossible to subdivide these lower rocks except on a broad lithological basis. The siliceous limestone and quartzite, however, recall the upper part of the Silurian and lower part of the Devonian systems as seen further east in the Himalaya, and may include the Muth quartzite, which is such a persistent feature of Himalayan stratigraphy.

Probable sequence.

So far, the sequence from the gneiss between Drosh and Gahiret up to the Upper Devonian of Shugram seems to offer no difficulties, and appears to be a continuously ascending one, at least from the apparently lowest crystalline limestone upwards. In fact, the sequence seems to be—

6. Upper Devonian limestone ;
5. Siliceous limestone and quartzite ;
4. Red shale ;
3. Conglomerate ;
2. Slate with some quartzite ;
1. Crystalline limestone ;

Granite and Gneiss.

The Reshun conglomerate.

Between the mouth of the Owir valley and Reshun, the most conspicuous rock is conglomerate ; blocks of it lie in the river-bed and the ground on either side of the road is strewn with it. All this transported material seemed to belong to the same rock, which is made up chiefly of pebbles of grey or white limestone, often crystalline, and quartzite ; trap was absent from the blocks I examined. Although there seemed to be some disturbance at the mouth of the Reshun valley, the general impression of the section was that of a continuous ascending sequence from the conglomerate to the Upper Devonian limestone ; at the same time both the shale and the conglomerate, though the latter is thoroughly indurated, looked suspiciously young for older Palæozoic rocks ; further ground for suspicion lay in the discovery among the limestone pebbles of a fragment containing the same fossils, — then supposed to be *Bryozoa* but now known to be *Orbitolina* (Pl. 31 fig. 4)—as I had found in the limestone associated with the volcanic series near Drosh. The apparent position of the conglomerate—below the Devonian—led me to infer that either the supposed bryozoan limestone must also be older Palæozoic and therefore older than the Drosh volcanics or that there was either a fault of great throw or else an inversion in the valley behind Reshun. The crushed and slaty appearance of the Drosh limestone was as favourable to one interpretation as to either of the others, while the fossils gave no clue, since I could not determine them macroscopically and, if Bryozoa, they might be of any age from Ordovician onwards. It was therefore preferable to take the simplest explanation, namely, that the sequence was normal and the Drosh limestone and the Reshun conglomerate both pre-Devonian. I adopted this as a working hypothesis during the remainder of my journey through Chitral, though my faith in it was subsequently shaken by the discovery of trap pebbles in blocks of what appeared to be the Reshun conglomerate at Awi, a village on the left bank of the Yarkhun river about twenty miles above Reshun. The rock was not *in situ* at that place and I hoped to meet it further on, but did not come across it again in association with beds of known age. There was no time to go back, as I had to reach the Darkot pass before it closed for the early summer months and the true sequence consequently remained doubtful. The discovery now that the supposed *Bryozoa* are fragmentary *Orbitolinæ* and that the conglomerate is consequently Upper Cretaceous or Tertiary necessitates complete revision of the sequence below the Devonian at Reshun, and this is only possible in the field. A conceivable explanation is that there are two conglomerates between which I failed to distinguish, one pre-Devonian and the other Tertiary; otherwise the most reasonable interpretation of the section is that there is a fault of great throw between the Devonian and the Tertiary. Disturbance is very pronounced along the valley on the opposite side to Reshun, and the hill-side has in places been reduced by faulting to little more than a rubbish-heap. I have also shown that there are indications of probable faulting on a large scale in the neighbourhood of Drosh, and the belt of gneiss—much of it a foliated granite—, which crosses the valley of the Chitral river between Drosh and Gahiret is also suggestive of a zone of fracture. It is unfortunate that the true sequence should be left in such a state of uncertainty. I may seem to have entered into unnecessary detail with regard to my difficulties over the Reshun section, but as there is no immediate hope of making a systematic study of the geology of Chitral, we shall probably be dependent for some time on the observations of travellers, who may be as restricted as I was in the matter of time and it is advisable to help them as far as possible to avoid the pit-falls by which I was entrapped and at the same time to specify the more important points that require elucidation.

The Reshun conglomerate, or one very like it, re-appears among crushed and foliated beds at several other points in Yarkhun, Yasin and Hunza, and if it is really a single formation and does not embrace two rocks of widely different ages, it will serve as a valuable guide in unravelling the structure of one of the most complicated areas in the Himalayan region. At present we know merely that to the north of the igneous and metamorphic belt of Dir and Swat, limestone and slate are overlain by a volcanic series, consisting of a coarse agglomerate below, followed by ash, trap and breccia and probably equivalent in age to the Panjal Trap. Below Drosh the volcanic series is associated—probably unconformably—with very crushed Orbitolina limestone; beyond the Shishi river it gives place to gneiss and crystalline limestone followed by a thick slate series with some quartzite. The relationship of the gneiss to the volcanic series is unknown, but the problem could be solved by detailed study of the structural conditions in the Shishi valley and in the neighbourhood of Reshun; the slate series was assumed by me to be pre-Devonian, possibly Ordovician or Cambrian and the—apparently underlying—crystalline limestone to be older still, but this inference depended on the supposed pre-Devonian age of the Reshun conglomerate, now a matter of considerable doubt since a travelled block of apparently the same conglomerate has been found to be not older than Cretaceous. The crystalline limestone and slate series may be equivalent to the Ashreth limestone and overlying slate which lies directly under the volcanic series at Mirkani; and if the latter is of the same age as the Panjal Trap, the two former must be Lower Carboniferous or older.

McMahon's correlation.

[In his interesting notes on the geology of Chitral already referred to (*supra* p. 272), Sir Henry McMahon describes two groups of conglomerate-sandstone-limestone, one in the neighbourhood of Mirkani, Drosh and Gahiret and the other at Reshun, and he is inclined to regard the one as the direct continuation of the other. The lowest member of the Mirkani-Drosh-Gahiret group is evidently the Mirkani volcanic agglomerate; the second member I have not been able to identify, as the only sandstone that I observed at Drosh was the soft Tertiary rock; the Gahiret limestone is unmistakeable. From what has been said above, it will be seen that it is not probable that the Mirkani agglomerate is represented at Reshun, while the age of the

Gahiret limestone is doubtful: it is, however, quite possible that it may include metamorphosed representatives of the Upper Devonian of Reshun. At the same time the conditions have proved to be much more complicated than was formerly supposed and in the presence of the intervening belt of gneiss we should not now be justified in grouping the Mirkani agglomerate with the Gahiret limestone. The supposed simplicity of the sequence was further responsible for leading General McMahon to suggest that the conglomerate-sandstone-limestone represented the Blaini series of the Simla area. Had he been able to study the Chitral rocks in the field he would undoubtedly have realised that there were no grounds for such correlation; there is indeed no lithological or stratigraphical resemblance between the Blaini series and any rocks that I have met with in Chitral.

Carboniferous shale series.

The Upper Devonian beds opposite Reshun and above Shugram are overlain by a thick series of paper- and needle-shales and quartzite. One thin bed of crinoid limestone was also observed in the shales. Further back in the hills, and below the village of Lun, the shale series runs to the foot of a line of cliffs formed of the Upper Devonian limestone evidently repeated by a fault. Above this is shale similar to the series just referred to. Above the village of Lun, shaly and slaty beds predominate, passing up eventually in the high ridge above the village into quartzite with some slaty calcareous beds. Above this the hills were completely snow-covered at the time of my visit, and it was impossible to ascertain the nature of the rest of the section. The shale and quartzite series is like a group of Palæozoic beds subsequently found in the Pamirs, where it underlies the great limestone series that I have called the Pamir Limestone. I cannot say if the latter is represented in the hills above Lun as they were under snow at the time of my visit, but the upper part of the Mesozoic group is not far off, for I found on the roadside at Mori Lasht, about four miles above the Golen valley, a travelled block of hippurite limestone. It may have come from the Owir section.

Devonian of Koragh spur.

From Reshun the road to Mastuj first of all follows the lower silicious limestone for some way, subsequently crossing it on the spur which juts out into the river on its left bank opposite to, and just above, Shugram. Here it passes up into a brown limestone with quartzite. The limestone is full of crinoid stems, all crystalline and not sufficiently well-preserved for determination. There is considerable disturbance and probably faulting here, but the limestone appears to pass up through alternation with shale into quartzite. On the ridge which turns the river just below Koragh, there is a good section of the Devonian beds. The scree from the ridge is full of the same fossils as were found by Col. Gurdon in the section opposite Reshun. Sometimes *Spirifer Verneuili* composes whole bands of rock of a thickness of as much as six feet; below these are bands of coral, and under that again a shaly bed with *Atrypa aspera* and trilobites. Each of these fossiliferous bands is separated from the others by a thin band of quartzite. Higher up the ridge the fossiliferous beds are underlain by dark shales passing down into brown and grey limestone full of corals. Below this again is a thick mass of pale-yellow and white quartzite, which one is tempted to regard as the equivalent of the Muth quartzite of the Himalaya.

Possible faulting.

The fossiliferous beds are overlain towards the end of the Koragh spur by quartzite like the underlying rock just referred to, and there seems to be a fault through the spur. I found no fossils in the quartzite, but it would be advisable to examine the higher parts of the spur behind the fossiliferous beds in the hopes of finding the rest of the Palæozoic group including the Lower Devonian limestone of Showar Shur. So far as the Upper Devonian fossils are concerned, this locality is a more prolific, as well as a more accessible, one than that above Shugram. As a rule, too, the fossils are very well preserved, and large collections can be made in the course of a few hours. I now regret that I did not spend several days here in examining this section and that of Owir in order to determine the complete sequence, but as I have already said, I was pressed for time, since I wished to leave Chitral *viâ* the Darkot pass, which is usually closed to traffic from the middle of April till July. It was also reasonable to expect that a complete section of the lower beds would be exposed further up the valley of the Mastuj river, but in this respect the Chitral valleys generally are most disappointing; one is continuously buoyed up with the hope of finding a good exposure of the sedimentary series round the next bend which, however, one turns only to find the sequence disturbed either by extensive faulting or by intrusive granite.

Probable sequence in Turikho.

Opposite Koragh the Mastuj river is joined by another broad stream which drains Murikho and Turikho, a large valley running up to the snowy peaks opposite Kala Panja. The valley is the structural continuation of that of the Mastuj river from Koragh downwards, and the sedimentary series of Owir and of the hills behind Shugram ought to be well exposed in it unless they have been confused by the intrusive granite of the Tirich Mir massif.

Above Buni the Mastuj river flows from east to west, and the Devonian beds appear to cross it and run along the high ridge between Turikho and the Yarkhun valley. At Awi the hillside is covered with blocks of conglomerate which have fallen from the cliffs above; the rock is superficially very like the Reshun conglomerate, but contains pebbles of dacite and Fusulina limestone. From Awi to Mastuj the rocks on the left bank of the river are crystalline limestone, slate and quartzite. The crystalline limestone is apparently the same as the rock found near Kes, between Drosh and Gahiret, and is presumably a continuation of that series. It continues up the Yarkhun valley to Jhopu, the prevailing rocks between Mastuj and that village being slates (often schistose), crystalline limestone and granite. The rocks are all highly altered, and the facies is a metamorphic one. In the neighbourhood of Jhopu, the strike, which has hitherto been on the whole SW-NE, gradually swings round and is almost W-E. From Jhopu the crystalline limestone runs up towards the Tui pass; this observation, however, was only made from a distance. Immediately below Jhopu the limestone forms cliffs on the left bank of the Yarkhun river; these are often beautifully polished and covered with glacial striæ.

Rocks between Koragh and Jhopu.

Jhopu lies at the southern end of the Ishpirin defile, which is an immense gorge cut through a range of granite and gneissose granite, the westerly continuation of the Sakez Jarab range at the head of Yasin. The gorge runs north-south and almost at right angles to the strike of the sedimentary series found at either end of it. The upper Yarkhun valley above the defile runs approximately east-west. At the northern end of the defile, about 2½ miles above the small village of Dubarghar, granite gives place to limestone, which forms great cliffs on either side of the river and also on the high hills on the right bank behind Turipotk, where the Koksum stream from the Shah Janali pass enters the Yarkhun river. Just above the small village of Yakhdan, rocks similar to the Reshun conglomerate, grit and crinoid limestone are found on the right bank of the river. All the rocks are much metamorphosed, and granite seems to prevail in all the higher hills, for it is the chief rock in the moraines

Granite and metamorphic rocks of Ishpirin defile and Yarkhun.

and in the river-bed. Behind Lasht, which is on the right bank of the river, the crinoid limestone series, which presumably represents the Devonian of Reshun, underlies a very thick series of black slate and white quartzite, which forms the high ridge behind (north of) the village. This extends up to the snow-line, where it is in contact with intrusive granite. It is probably the series already observed above the Upper Devonian in the hills behind Shugram. These rocks—conglomerates, limestones and slate with intrusive granite—continue all the way to Petus, the last village in the Yarkhun valley. The strike has gradually become more and more equatorial and has determined the course of the Yarkhun valley. The high peaks to the south of Petus are probably composed entirely of the granite and gneiss seen in the Ishpirin defile. At Petus there is a warm spring, the temperature of which, however, is low, probably between 60° and 70°.

Above Petus the prevailing rocks in the Yarkhun valley are slate and quartzite, with some limestone and granite in the high hills on either side. Granite is also intrusive in the sedimentary beds, where the road to the Baroghil pass crosses the Yarkhun river, at the bridge below Dasht-i-Baroghil. Here the river rushes through a deep and narrow granite gorge, which is crossed by a small foot-bridge.

The Baroghil Pass.

The Dasht-i-Baroghil is a shallow valley some four miles long and half a mile wide, covered with moraine material. It appears to have been once the bed of a glacier which flowed from the snow-fields above Petus,—now embracing the Chatiboi and Darkot glaciers—into the Oxus in Wakhan. Huge erratics of granite, which must have been derived from the high peaks to the south-east, are found stranded on the slopes on either side of the Dasht-i-Baroghil. On the right bank of the river, and between the Dasht-i-Baroghil and the Shawitakh pass, there is an extensive series of sedimentary rocks undisturbed by granite. At the time of my visit (May 5th to 8th, 1914) almost all this country was under snow, and it was impossible to find a complete or continuous section. The Lower Devonian fossils described by Mr. Cowper Reed (*Rec. Geol. Surv. India*, XLI, 86, 1912), which were collected by Major Grant in 1898, were found near Showar Shur in the Yarkhun valley, about 8 miles beyond the Baroghil pass. They occur in a dark and rather fetid limestone, and I failed to find anything resembling this rock in the Baroghil sections, nor could I find boulders of it among the moraines. It is probably obliterated by the granite at the southern end of the Dasht-i-Baroghil; the hills on the west, where it might also be found, were inaccessible on account of snow; so also were the hills between the Shawitakh and Karambar passes; they looked promising, however, and would certainly supplement considerably the Baroghil-Shawitakh section.

Devonian.

The southern ascent to the Dasht-i-Baroghil is, as already stated, over granite. The next rocks observed above the granite belong to a series of quartzite and siliceous limestone, all much crushed and often quite shaly. The limestones contain very badly-preserved specimens of *Spirifer*, which are too poor for determination, but may be *Sp. Verneuili.* They are found below a thick bed of quartzite which forms the southern shore of the small lakelet at the southern end of the Dasht-i-Baroghil. On the northern shore of the same lakelet, crushed limestones and quartzites were found, the former containing corals, which, however, were not determinable. At Baroghil Ailak, this series passes up through thin-bedded, grey, brown-weathering limestone into shale and quartzite, which continue for a considerable distance along the ridge separating the Dasht-i-Baroghil from the Yarkhun valley. The shale and quartzite series passes up through thin-bedded limestone full of crinoid stems into shale and shaly limestone containing

Carboniferous and Permian of Yarkhun river between Baroghil Ailak and Shawitakh.

Athyris, Spirifer and *Fenestella.* An outcrop of this fossiliferous bed is seen on the long ridge running down into the valley above the stone huts of the first grazing-ground on the right bank of the Yarkhun river above Baroghil. About 50 feet above the first fossiliferous layer, shaly limestones contain, in addition to a similar fauna, also *Spirifer rajah.* The latter bed is overlain by hard and splintery grey limestone full of small white specks, which are altered *Fusulinæ.* About a hundred feet higher up, a dark grey, very hard band of limestone contains corals and a *Bellerophon* very like *B. Jonesianus* Kon. of the Salt Range. Above these there is a band full of calcareous algæ and well-preserved *Fusulinæ.* The same limestone extends for about 300 feet higher up, becoming shaly above. It is full of the same *Bellerophon* and calcareous algæ. Corals are numerous, and include species of *Michelinia* and *Lonsdaleia* (*L. indica* Waag. and Wentz). This limestone is followed by about 50 feet of quartzite overlain by a hard, dark grey, splintery limestone with *Producti, Chonetes* and *Fusulinæ.* The *Producti* include *P.*

semireticulatus Mart., *P. Abichi* Waag., *P. Konincki* Vern., and *P. cora* d'Orb., and occur chiefly in one band about 50 feet above the base of the limestone. The *Chonetes* occur about 2 feet higher up, and are overlain by Fusulina limestone. About 10 feet higher up, another band occurs with *P. cora* d'Orb. and *Chonetes*. *Producti* and *Chonetes* then extend for some considerable distance up through the limestone, the next fossiliferous band being a shaly limestone containing *Derbyia* sp. and *Fusulina*. Above this is a solid mass of Fusulina limestone. The total thickness of the whole of this fossiliferous limestone band from the top of the underlying quartzite is about 500 feet. It is overlain by pale-grey limestone, with one thin band full of corals. This is followed by a band of dark ferruginous grit, which has the appearance of having been brought in by a fault. Above this again is dark grey limestone like the lower part of the Fusulina limestone but apparently unfossiliferous; it is overlain by a great thickness of thin-bedded pale-grey limestone, very hard and compact and in beds of from six inches to a foot thick. This limestone is part of the very thick series which extends up to, and over, the crest of the Shawitakh pass, sometimes pale grey and compact, sometimes darker, and occasionally shaly. In its upper beds it resembles the upper Triassic limestone of the Himalaya. It probably corresponds, at least in part, to the Pamir Limestone. I failed to find any fossils in it, but my examination of it was very cursory as most of the country was under snow. Its position overlying the Fusulina limestone indicates a Triassic age, at least for the lower part of it.

Triassic limestone of Shawitakh.

Fauna of the upper Palæozoic beds.

The fossiliferous series seems to extend from Upper Devonian to Permian, the beds at the small lake at the south end of the Dasht-i-Baroghil being probably, as already stated, the representatives of the Upper Devonian of Koragh and Reshun, while the overlying slates and quartzites are presumably Carboniferous. The fauna of the fossiliferous beds recalls in many respects that of the Productus Limestone of the Salt Range. The following partial list of the fauna is based on a rough preliminary examination of my collections, and includes all the fossiliferous horizons observed:

Productus semireticulatus Mart.
,, *Abichi* Waag.
,, *Konincki* Vern.

Productus cora d'Orb.
Spirifer rajah Salt.
,, *fasciger* Keys.
Derbyia sp.
Chonetes sp.
Athyris Royssii Lev.
,, *subexpansa* Waag.
Pseudomonotis sp.
Bellerephon cf. *Jonesianus* Kon.
Pleurotomaria sp
Fenestella sp.
Protoretepora sp.
Fusulina sp.
Schwagerina princeps Ehr.
Lonsdaleia indica Waag. and Wentz.
Michelinia sp. and many other corals.

This fauna is evidently Upper Carboniferous to Permian.

This is the most extensive section that I found in Chitral, and would well repay further study. My visit, however, was paid too early in the year; in June or July the hills on the west of the Dasht-i-Baroghil would probably be more or less free from snow and ought to yield a fine section.

Rocks of hills across the Oxus.

From the top of the Shawitakh pass the hills on the other side of the Oxus are clearly seen to be composed of a black slate series which I subsequently examined along the boundary between the Great Pamir and Wakhan. It is the same as the shaly series underlying the Pamir Limestone at Aktash, and is almost certainly Upper Palæozoic. What its relationship is to the Baroghil-Shawitakh Palæozoic series has not been determined, but it presumably represents the slate and quartzite series which I have referred to the Carboniferous. The apparent absence from the greater part of the Pamirs of the Fusulina limestone[1] and of the associated fossiliferous beds seems to indicate that the calcareous facies of the Upper Palæozoic of Chitral is replaced further north, as it is in the Himalaya, by a shallow water facies consisting of shale and sandstone (slate and quartzite).

[1] One fragment, a small pebble, of Fusulina limestone was found near Aktash in the Russian Pamirs (*infra* page 310).

II.—Yasin, Gilgit and Gujhal.

The Darkot Pass.

The Yasin valley is separated from the Upper Yarkhun by the Sakez Jarab range of gneiss and granite and its westerly continuation already referred to. At the head of Yasin the range is crossed by the Darkot Pass, which was formerly accessible both from the north-east and from north-west along the two Darkot glaciers. The former route, however, is now said to be no longer practicable, and I approached the pass from Petus. Owing to the necessity for starting shortly after midnight, and also to a snow-storm, which came on some time before daybreak and continued throughout my march, it was impossible to see the hills on either side of the glacier. It is probable, however, that they are composed of gneiss and granite, which was the rock found on the Darkot Pass and which extends down to the small village of Gakshi at the head of the Yasin valley. A short distance below this village, at the old frontier fortifications of Darband, the metamorphic rocks give place to a series of black shale and slate dipping to the north and underlain first by shaly limestone and subsequently by a thick series of massive grey limestone.

Fusulina limestone in Yasin.

The shaly limestone contains large numbers of *Bryozoa* and *Fusulinæ*. It also contains bands full of *Producti*, which have been crushed almost flat. With the exception of the *Bryozoa* and the *Fusulinæ*, all the fossils in these beds are so badly crushed as to be indeterminable specifically. The shaly limestone is associated with paper shales containing impressions of *Derbyia* and what appeared to be a *Lyttonia*. In spite of the bad state of preservation of the fauna, I think there is little doubt that this series represents the Fusulina limestone and associated beds of the Baroghil area. The underlying massive limestone, which forms high cliffs on either side of the river, is grey and splintery, and yielded no fossils. All these rocks strike west-east, and they almost certainly represent the continuation of the sedimentary series of the Yarkhun valley between Jhopu and Mastuj. The strike, which, throughout Chitral, followed approximately the trend of the chief hill-ranges, has gradually swung round from NE-SW to E-W with a tendency at the Baroghil and also in Upper Yasin to assume a slight southerly deflection.

The fossiliferous series of Darband appears, as already stated, to be underlain by a massive limestone, which, again, is underlain by slate, often calcareous. The series is intensely folded, and the limestone is not really so thick as it appears to be. It is faulted and brecciated, and in the absence of fossils it is impossible to say whether it is younger or older than the limestone with *Fusulinæ* and *Bryozoa*, since the disturbance is such that the beds may quite possibly be inverted. I have assumed, however, that the sequence is normal and that the massive limestone underlies the fossiliferous beds. As will be seen from the rough sketch-map, the sedimentary beds are merely a fragment remaining in the midst of gneiss and granite. The underlying calcareous slates are seen on the northern side of the valley at Darkot, and appear to extend across into Ishkaman. Below Darkot the valley is bounded on either side by steep cliffs of metamorphic rock comprising hornblende gneiss and metamorphosed grits and pebble beds and subsequently granite, which latter extends to Amurchat. The presence of metamorphosed grits and pebble beds below Darkot suggests the continuation of the conglomerates and grits of Chitral, and at Amurchat the fans of the side streams are full of fragments of rocks like the Reshun grit and conglomerate, while a little below the village immense blocks of the conglomerate are seen in the river-bed. They appear to have been brought down from the hills on the left bank of the river. A little further down the main valley, the hills on either side are composed of slate and quartzite very like the series prevailing between Gahiret and Reshun in Chitral. These beds dip first to the north, but are much contorted and faulted. At the junction of the Tui and Darkot rivers, the quartzites are almost vertical, dipping, however, at a high angle to north-north-west, and are overlain by grey and whitish crystalline limestone having a similar dip. Below these, again, are quartzite, slate and, opposite Sandi, brecciated limestone. All these beds are highly metamorphosed, intensely faulted and brecciated, and no trace of fossils was observed.

Rocks between Darkot and Yasin villages.

The same series appears to continue through the Dasht-i-Taus to the village of Yasin, and I at first regarded the beds in the cliffs immediately behind the Rest House on the right bank of the river as part of the same metamorphic series. Closer examination, however, proved that the latter beds were highly crushed and indurated sandstones with thin bands of equally crushed shaly limestone. The shaly limestone, which is almost vertical, proved, on examination,

Upper Cretaceous at Yasin.

to be full of *Hippurites*, which stand out in lumps all over the bed. The fossils are intensely crushed, sometimes almost completely flattened. This Hippurite limestone is underlain by indurated sandstone followed by calcareous shale with *Orbitolina*, which, again, overlies a conglomerate composed chiefly of pebbles of trap. Below the conglomerate there is a great mass of trap, which, with granite, extends practically all the way to Gupis at the junction of the Yasin and Ghazar rivers. The trap is interrupted by the intrusive granite between the villages marked Duman and Sundri on the map,—names, however, which appear to be locally unknown. The trap seems to be of the usual type characteristic of the Panjal Trap of Kashmir, and the lower boundary of the Yasin Cretaceous beds is therefore an unconformable one, the whole of the pre-Cretaceous portion of the Mesozoic group being absent. In fact we seem here to have found another point on the line of the great cenomanian transgression with which we are familiar in North-Western India and Afghanistan (*Mem. Geol. Surv. India,* XXXIX, 80, 81 [1911]). How these beds are bounded on the north I cannot say. Only a detailed examination of the area will enable one to determine this. Possibly they are separated from the slate and quartzite series by the fault running along the valley of the Naspar Gol (stream), which joins the main valley from the west at Yasin.

Panjal Trap in Yasin.

Below the village marked Sundri on the map, the intrusive granite gives place to trap again for a short distance, but this is soon succeeded by vertical beds of crystalline limestone penetrated by veins of trap. This is succeeded to the south by a conglomerate followed by metamorphic schistose and gneissose beds with intrusive granite and coarse dioritic rocks like those met with between Sado and Rabat in Dir. The crystalline limestone and conglomerate may possibly represent the agglomeratic slate and associated limestone of Kashmir. This is merely suggested as an impression gained from the general lithological sequence between Yasin and Gupis; it is merely tentative and I lay no stress on it, for the futility of attempted classifications based purely on lithological association is as patent in Chitral and the Pamirs as it is in the Himalaya.

Granite and metamorphic rocks of Gilgit and Hunza.

In his "Notes on the Geology of Gilgit,"[1] General McMahon has described a number of specimens of rocks collected, partly by Sir Henry McMahon and partly by Captain (now Sir) J. R. Roberts, in the

[1] Q. J. G. S., LVI (1900), 337-368.

Gilgit Agency including Yasin and Hunza. A considerable number of these specimens came from the Gilgit-Gupis road, and consist of granite, diorite, amphibolite, crystalline limestone and various schists. This series extends all the way from Gupis to Gilgit along the valley of the Yasin river, which runs somewhat obliquely across the strike. From Gupis to Roshan the prevailing rocks are dioritic, but at the bend of the river at the latter village crystalline limestone is found dipping south-west and penetrated by bands of trap which sometimes run parallel to, and sometimes cross, the planes of foliation. There is a great amount of disturbance here, including apparently an inversion, and the limestone and trap are occasionally intermingled in such a manner as to form a rock resembling a calcareous conglomerate, presumably of autoclastic origin. The metamorphic series, consisting of crystalline limestone, calc-schists, calc-gneisses, quartzites and amphibolites, continues all the way to Gilgit, penetrated by, and sometimes giving place to, great masses of granite. From Gilgit to Hunza, the road, which follows the valley of the Hunza river, runs directly across the strike of the rocks and between Gilgit and Nomal crosses the same metamorphic series. Between Nomal and Chalt the prevailing rock is granite, with hornblende schists and hard fine-grained gneisses. Associated with these are rocks which appear to be metamorphosed traps and also a highly metamorphosed bed of conglomerate now almost a gneiss.

Many of these rocks have already been described by General McMahon, and I agree with him in regarding this metamorphosed series as the altered representatives, at least in part, of the sedimentary systems of the North-Western Himalaya. Between Chalt and Nilt, the rocks of the Budalas hill-side consist of a calcareous series dipping at high angles to the north and overlain by crushed conglomerate resembling the Reshun rock. Above Chalt, the valley of the Hunza river follows the strike, and has been cut out along a crushed anticline. Crystalline limestone is seen on both sides of the river, and appears to be overlain by the conglomerate series.

Sedimentary rocks of Gujhal.

The calcareous series continues on up the river to Ataábad; from Aliabad onwards, it is full of granite intrusions, the "stink-stone" referred to by General McMahon being a very coarse white and grey crystalline limestone often containing phlogopite. From Ataábad granite and schist continue all the way to Husaini, a small village a short distance above Gulmit, where they suddenly give place to dark slates, chiefly calcareous, dipping at high angles to the south. These continue most of the way to Pasu, with occasional bands of grey quartzite which weather to a creamy yellow. At Pasu the beds are much folded and faulted, and a thick limestone series forms high cliffs on either side of the river. In the hills on the right-hand side of the Pasu glacier, there is a dark limestone resembling an altered coral limestone and like the coral limestone exposed on the northern shore of the small lakelet at the southern end of the Dasht-i-Baroghil. This limestone also yielded some indeterminable fragments of brachiopods. It differs from the massive limestone which forms the high cliffs behind Pasu and which is a hard light-grey splintery rock apparently the same as the main mass of limestone forming similar cliffs at Darband in the Darkot valley (see p. 294). The latter limestone west of Pasu is underlain by slaty limestone dipping at high angles to the south, but the junction appears to be faulted. The slates are underlain by massive grey limestone, and a short distance above Pasu a block of dark-grey limestone found on the scree at the foot of the cliffs yielded a badly-preserved fragment of ?*Cyathophyllum.* Further up the valley the ridge on the northern side of the Batur glacier is formed of slate overlying limestone; the junction again appears to be faulted. On the right bank of the river, about 1½ mile above the Batur glacier, an old river flat is covered with blocks of conglomerate exactly like the Reshun conglomerate; it is considerably crushed, but its resemblance to the Reshun rock is otherwise most striking. Blocks of quartzite, grit and pebble-bed also occur in the same locality, and all appear to have fallen from the high hills on the right bank of the river. About one mile below Khaibar, I found blocks of limestone very like an altered Fusulina limestone, but, owing to their state of alteration, the included bodies could not be definitely identified as *Fusulinæ.* All the rocks in this locality have a steady dip to the south, and a strike, for the greater part, of east-west. At Khaibar the strike swings to WNW-ESE or even NW-SE, but this is only local. Up to Khaibar, therefore, the whole of Gujhal consists in the main of an alternating series of calcareous and slaty rocks. In the south, between Hunza and Husaini, they have been altered by granite and converted into schists and gneisses. Above Husaini there are slates and limestones, and apparently also the Reshun grit and conglomerate. In view of the strike throughout the intervening area, there is, I think, no doubt that these rocks represent the Palæozoic and Mesozoic beds of Chitral and Yasin. The conglomerate was not seen *in situ* and its relationship to the slates and limestone not determined. At and above Khaibar, the Hunza river runs in a deep valley between cliffs of limestone which rise to several thousand feet above the river. Disturbance has been very considerable, and the limestone is greatly folded and often converted into a fault breccia with a grey calcareous ground-mass of the consistency of table-salt. For about 1½ mile below Murkhun, on the left bank of the river, blocks of limestone, evidently derived from the overhanging cliffs, contain white calcite sections of large lamellibranchs which I attribute doubtfully to hippurites. Just below Gircha, the cliffs on the left bank of the river consist of dark grey limestone underlain by a black slaty limestone alternating with beds of slate. These pass down into slaty quartzite and the section recalls that of the Baroghil pass. Unfortunately, however, such fossils as occur are too fragmentary and too greatly metamorphosed for determination. Just below Gircha, a hard splintery dark-grey limestone is seen, with intrusions of trap, and at Gircha itself the hills are composed of dark thin-bedded slaty limestone. On the whole, the facies from Khaibar to Gircha is essentially a massive limestone one, and includes probably both Upper Palæozoic and Mesozoic beds. Here and there in the river-bed, occasional boulders of the supposed Reshun conglomerate are found, but they are all small and have probably therefore travelled some considerable distance.

A few miles above Misgar, a fan of the stream joining the Hunza river at Sost contains many boulders of what appears to be a metamorphosed crinoid limestone.

Just above Khodabad, quartzites and slates are exposed in the cliffs on the left bank of the river and dip at high angles to the north.

Slate series and Pamir Limestone near Misgar.

About 3 miles below Misgar, the hills on either side of the river are composed of dark shales exactly like the series already referred to as occurring in Chinese Turkestan and the Russian Pamirs, where they underlie the Pamir limestone and are almost certainly of Upper Palæozoic age. No fossils were observed in them in the neighbourhood of Misgar. On a moraine below that village, however, I found a block of dark slaty limestone containing *Spirifer* and many small *Bryozoa*. Other fragments of rocks found in the same neighbourhood consist chiefly of limestone derived evidently from the higher hills on the right side of the valley. These hills consist of slate and shale below and limestone above. The section, which appears to be a good one and less affected by metamorphism than most of the rocks in Gujhal, would probably be worth studying. Slate is seen for some little distance above Misgar, but is soon replaced by granite which continues all the way to the Mintaka pass.

III.—The Taghdumbash and Russian Pamirs.

Shale and slate series (Sarikol shales) of Chinese Turkestan.

Immediately across the Mintaka pass the granite gives place to a dark slate series, which extends throughout the whole of the south-western corner of Chinese Turkestan, including the Karachukar valley and its tributaries, such as Kukturuk, Tagharmansu and others, as far down as, and to some distance below, Beyik. The series here consists in the main of slates, occasionally calcareous as at Lup Gaz, quartzites, volcanic rocks, needle-shales, and occasional bands of limestone. In the higher hills, such as those surrounding the Mintaka pass and those at the heads of the Kukturuk, Tagharmansu and probably also the Beyik valleys, the series is chiefly slaty, owing to the neighbourhood of intrusive granite and other igneous rocks; where, however, the igneous rock is some little way off, needle-shales take the place of slates and vividly recall the Spiti Shales of the Himalaya. The series extends to the west, and is clearly the continuation of that seen from the Baroghil and Shawitakh passes extending far to the north on the right bank of the Ab-i-Panja (Oxus). It was, in fact, subsequently met with by me in the mountains between the Great Pamir and Wakhan—the Wakhan or Nicholas range,—whence it appeared to be perfectly continuous through the Kara jilgha and Wakhjir passes into the south-western extremity of the Taghdumbash Pamir. Here and there thin bands of crystalline limestone run through it, one such band being conspicuous in the hills between the Tagharmansu and Karakokti valleys. A similar—possibly the same—band was met with in the Great Pamir running from Salangur lake through the hills on the right side of the Urtabel valley.

Igneous rocks associated with the slate series.

A marked feature of this slate series wherever met with in the Pamirs is the presence in it of great quantities of igneous material. When I first met with the latter in the Taghdumbash Pamir, I was doubtful as to whether I was dealing with subsequent intrusions or with contemporaneous flows. In the Karakokti valley it is found as a black band of trappean rock, which seems to be associated with granite and overlies slate (altered needle-shale) and quartzite; it appears to be interbedded, but is really a sill. Further down the Karachukar valley the hills on the left side between Mintaka and Beyik appear from the opposite side of the river to be composed of dark trap with no perceptible bedding, while on the right side of the valley grey and black igneous rocks replace the slate series, which, however, is found again at the mouth of the Sarik (Sara) jilgha, where the igneous element is clearly intrusive; the prevailing type is the same as the Karakokti rock. In the Little Pamir the slates are penetrated everywhere by intrusions of dark igneous rock, which is perhaps the same, although I have no specimens by which to verify this microscopically. I am indebted to my colleague, Mr. H. Walker, for the following account of the microscopic characters of the rocks from the Karakokti and Karachukar valleys in the Taghdumbash Pamir:

"These rocks have undergone considerable alteration, but sufficient of the original minerals and structure remains to enable one to identify them as belonging to the Andesite family. Some contain much more quartz than others, and this causes one to suggest that the former should be regarded as dacites and the latter as quartz andesites.

The rocks are characterised by excellent phenocrysts (Pl. 31 figs. 1, 2). The most obvious are quartz. These are sometimes well-shaped but are more frequently irregular with corroded edges, and with inclusions of the ground-mass. The felspar phenocrysts are less obvious, for, owing to the degree of alteration, they do not stand up well from the ground-mass. They are plagioclase, are idiomorphic, and are usually well-formed. In all cases, they are much altered, with the formation of sericite and calcite, but the alteration has not proceeded to such an extent as wholly to destroy the lamellar twinning.

In all the slides the ferro-magnesian phenocrysts are now represented by alteration products after hornblende (Pl. 31 figs. 1, 3). In the slide carrying the greatest number of quartz phenocrysts the original hornblende crystals are now aggregates of pale-coloured chlorite, quartz and titanite (?); whilst in another slide it has altered to a deeper-coloured chlorite with separation of a small amount of ferruginous material. In the other cases, decomposition has proceeded until only a little calcite and iron-oxides remain. In several cases these oxides have leached into the ground-mass and stained it red. In one case only (where there are few quartz phenocrysts) are there indications of mica in conjunction with hornblende. The long narrow crystal forms with other shorter, broader, but jagged-ended forms (all replaced by iron oxides) point to mica as an original mineral constituent. In those slides in which quartz phenocrysts are not very abundant and where also the ferro-magnesian minerals are now replaced by iron oxides and not by chlorite, apatite is found (Pl. 31 fig. 3). It occurs as short stumpy prisms. Oxides of iron are included in the apatite, and are usually arranged peripherally. Occasionally flakes of hematite are to be seen in the body of the apatite crystal.

In all these rocks the ground-mass is micro-crystalline, in some cases more coarsely crystalline than in others. In the dacites both quartz and felspar can be recognised in the ground-mass. In the more finely crystalline rocks it is not possible to recognise the younger generation of either felspar or quartz. A certain amount of the ground-mass contains secondary carbonates."

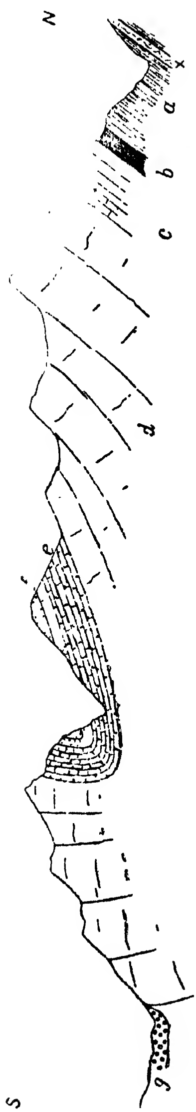
Amongst the pebbles collected from the Reshun conglomerate at Awi I have found typical specimens of the andesite (Pl. 31 fig. 2), which is, therefore, pre-Tertiary. A lower limit for its age is given by the slates which are certainly as young as Upper Palæozoic and may even extend up to Triassic. In the Little Pamir the rock intrusive in the slate series near the mouth of the Shindi valley has penetrated the uppermost beds of shale and has even affected the lower part of the limestone; I have not found the intrusive rock in the Pamir Limestone proper, but my examination of that formation was not extensive enough to justify the statement that it is not penetrated by the andesite. The question of the age of the latter must therefore be left in this unsatisfactory state of doubt; it is unlike any of the members of the Panjal Trap series, but resembles in some respects the so-called porphyries and porphyrites of the Tian Shan[1] and Ferghana.[2] Both in the latter province and in Bokhara an extensive volcanic series is associated with the uppermost Palæozoic beds.

Below Sarik jilgha granite replaces the sedimentary series and continues to about 3 miles below Beyik, where it gives place to limestone which strikes ESE-WNW and dips at high angles to NNE. At first the limestone is crystalline and associated with gneissose beds, but it soon passes into a hard grey and brown rock containing many badly preserved remains of fossils which include corals and lamellibranchs. This is the south-easterly continuation of the rock that I have named the Pamir Limestone and which is the most conspicuous rock in the south-eastern

[1] G. Romanowski: *Materialien zur Geologie von Turkestan.* Lief. 1 (1880).

[2] V. Weber: Recherches géologiques faites en 1904 dans la province de Syr-Daria. *Bull. Com. Géol., Petrograd*, XXIV, 347 (1905).

part of the Russian Pamirs. In the hills on the left bank of the river opposite Ujadbai, the massive limestone is overlain by thin-bedded and shaly limestones with shales, followed by an unaltered dark false-bedded sandstone with a lateritic bed at its base. The sandstone is evidently a fluviatile one, and is perhaps the representative of the Tertiary beds of the Indus valley in Ladak. The rocks here form a syncline. The sandstone which I have referred to the Lower Tertiary is underlain by beds containing gastropods and lamellibranchs, and immense numbers of spines and other fragments of echinoids. The fauna is so badly preserved and so fragmentary that I was unable to find anything determinable ; the general aspect of it, however, seems to be Cretaceous.[1] Below the shaly limestones massive grey limestone is again exposed in the hills on the left bank of the river below Ujadbai. It is underlain by a bright-red, broken limestone which passes down through creamy-yellow beds into a black carbonaceous shale with



g. Recent gravels of Karachukar valley
f. Dark sandstone (? Eocene)
e. Thin-bedded limestone and calcareous shale (? Cretaceous)
d. Pamir Limestone
c. Thin-bedded limestone at base of Pamir Limestone
b. Carbonaceous shale
a. Dark shale (Sarikol Shales)
x. Igneous sill in Sarikol Shales

FIG. 1. *Section on left side of Karachukar valley opposite Ujadbai.*

[1] I am indebted to my colleagues, Messrs. G. H. Tipper and G. de P. Cotter for confirmation of this view.

layers of quartzite. Below this again dark beds of shale with carbonaceous bands extend for miles along the river into the Taghdumbash Pamir. Here and there infolded masses of the Pamir Limestone and what seems to be a lower belt of limestone are found among the shaly series.

The Sarikol Shales.

At Acheqtash on the right bank of the river, there is a warm sulphur spring, and here, as also in the hills on the opposite bank, the black carbonaceous shales are associated with gypsum and are so exactly like the Angara (Saighan) series of Northern Afghanistan that I assumed without hesitation that they were merely the easterly continuation of that series. Their association, also in the hills opposite Acheqtash, with black needle-shales full of concretions and apparently perfectly identical with the Spiti shales of the Himalaya led me to suppose at first that there was here a passage between the freshwater Angara series and the marine shallow-water facies of the Himalayan Jurassic. The resemblance to the Saighan (Angara) series and associated rocks, was complete even to the beds of gypsum and the red calcareous bands at the base of the massive limestone, exactly as at the junction between the Jurassic and Cretaceous in certain parts of Afghanistan. It would be difficult to find a more complete exemplification of the fallacy of attempting to base stratigraphical correlation on lithological resemblance, however complete. Anyone familiar with the Upper Mesozoic of Northern Afghanistan could have no hesitation, in the absence of fossils, in identifying the carbonaceous shales and the massive grey limestone (Pamir Limestone) of the Taghdumbash Pamir with the Saighan series and Upper Cretaceous limestone of Northern Afghanistan; and for some considerable period I was under the delusion that this identification was the correct one, especially in view of the fact that the only fossils that I had found in any part of the limestone at that time appeared to be Cretaceous. Subsequent opportunities for studying both the shaly series and the Pamir Limestone in the Russian Pamirs proved that this correlation was incorrect and that the limestone was probably Cretaceous only in its uppermost layers and included also Jurassic and Triassic horizons.

Deceptive resemblance to Angara series.

The Taghdumbash Pamir from the point at which the course of the Karachukar river suddenly takes a right-angled bend to the north is to a great extent covered with glacial deposits, which extend to a thousand feet or so above the present valley bottom. The dark shaly series and massive limestone, however, continue on the left side of the river in the hills constituting the southern part of the Sarikol range. The strike is NW-SE and the same beds appear to constitute all the hills far to the east on the right side of the Taghdumbash Pamir. Usually these beds are greatly folded and disturbed and also unfossiliferous, for although I examined them in considerable detail in the Pislang and neighbouring valleys to the west of Acheqtash, I was unable to find any determinable fossils. The needle-shales, which so exactly resemble the Spiti shales, are full of concretions, but although I broke open many dozens of them, I found no fossils; their centres usually consist either of small nodules of marcasite or of limonite pseudomorphous after marcasite. A few miles north of Dafdár streams on either side of the river bring down fragments of slate, schist, calc-schist, hornblende-schist and various dioritic rocks. On the left side of the river, the high peaks of the Sarikol range consist of granite, and the metamorphic rocks just mentioned are the result of the modifications produced by its intrusion into the sedimentary beds which have been altered and in places absorbed. The hills on the right side of the valley between Jargal Gumbaz and Tashkurghan consist entirely of these metamorphosed sediments with intrusive granite; they include biotite-gneiss and schist, hornblende-schist, crystalline limestone and calc-schist, all pierced by bands of coarse granite.

Metamorphism of shales and limestones of Sarikol range.

From Tashkurghan I followed the route taken by Stoliczka in 1874, going south-east *viâ* Jangalak, Kengshubar and Nezatash to Aktash on the right bank of the Aksu (Murghab). From Tashkurghan to Kengshubar one follows a narrow precipitous valley often only a few yards wide and closed on either side by such steep walls that it is often necessary to wade along the bed of the stream for long distances. The valley cuts through the Sarikol range, the rocks of which are here entirely crystalline. They consist chiefly of granite, pyroxenite, gabbro and diorite in the centre passing out into banded gneisses and schists full of granite intrusions. In the neighbourhood of Kengshubar the sediments become less metamorphosed, and are represented chiefly by slate. Apparently, this part

Crystalline rocks of the Sarikol range.

of the range represents in the centre complete absorption of the sediments by granite and the recrystallization of the whole in the form of more basic varieties, such as gabbro, diorite and pyroxenite. Further out the absorption has been less complete, but the sediments have been highly metamorphosed and recrystallized. Still further away from the central core the intrusive rock almost disappears, and the effects of the metamorphi m are chiefly dynamic. At Kengshubar slates again prevail, and pass up, in the neighbourhood of Nezatash, into dark slaty limestones and slates with some quartzite, overlain again by needle-shales which are succeeded by the massive grey Pamir Limestone. Disturbance is everywhere very marked, faults are numerous, and for considerable distances the folds are occasionally inverted. This appears to be the case at Nezatash. As already recorded by Stoliczka, a black felspathic rock is found intrusive in the shales about a mile and a half above Nezatash. It occurs both as dykes and sills. A little further up, the valley narrows considerably and is enclosed everywhere by high walls of the grey Pamir Limestone, which is greatly folded and dips at a high angle. Where the path leaves the main valley to follow a side stream which comes down from the Lakhshakh (Nezatash) pass, the stream is full of blocks of limestone with sections of lamellibranchs. Nothing could be extracted from the rock, but the sections appeared to me to resemble those of hippurites. Stoliczka, however, has already attributed them to *Megalodon*,—a view which is more probably the correct one. The valley at the eastern foot of the Lakhshakh pass is filled with black shales exactly like the Spiti shales but no doubt the same as those already observed in the neighbourhood of Acheqtash. On the left bank of the stream they dip under the limestone and contain fragmentary *Rhynchonellidæ*. Both here and higher up the valley, they are full of concretions, from which, however, I failed to obtain any fossils. The same belt of shale runs westward and forms the low col crossed by the Lakhshakh pass leading into the Russian Pamirs, while the valley below the col is completely surrounded by high limestone cliffs. The shales on the ascent to the pass also contain many concretions, which here for the first time yielded fossils; the latter are badly preserved but resemble *Trigonia;* there is also a small lamellibranch like a *Myophoria*. Nothing, however, was definitely

Sarikol Shales and Pamir Limestone at Nezatash.

determinable. On the summit of the pass there is a bed of shaly limestone almost entirely made up of small fragments of brachiopods. From these I obtained crushed specimens of *Halorella*. To the west of the pass the Shindi valley, which leads down to the Aksu (Murghab) at Aktash, soon opens out, and the hills on either side consist of dark shale capped by grey Pamir Limestone. Folding and faulting have been very considerable, but a clear section on the left side of the valley opposite the mouth of Kizil jilgha shows the junction between the shales and the limestone. The former resemble more than ever the Spiti Shales and here too are full of concretions in which I found no fossils.

Halorella band.

The small stream (Kizil jilgha) which joins the main stream from the pass at about 5 miles above the mouth of the latter, flows in from the north approximately across the strike of the local rocks. Near the head of this valley the black shales are underlain by very compact sandstone, with some shale, passing down into a great thickness of conglomerate, which is coarse in places but consists for the most part of a reddish-brown sandstone with pebbly layers. This is like the conglomerate seen in the hills opposite Acheqtash. The sedimentary rocks in this valley are full of dykes and sills, mostly fine-grained, but including also coarse pyroxenite.

Sandstone and conglomerate of Kizil jilgha.

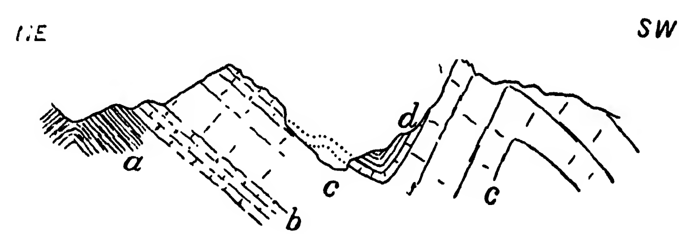
The presence of *Halorella* on the Lakhshakh pass shows that the Pamir Limestone there is at least in part Triassic, while the associated shales probably belong also to the same system. None of the underlying rocks in the Kizil jilgha yielded any fossils; the age of the main mass of the shales and underlying conglomerates is, therefore, unknown, but they must be presumed to include members of the Upper Palæozoic group. This, indeed, is the conclusion to which Stoliczka had already come forty years before, and, so far as this part of the sequence is concerned, I have been able to add nothing to his observations.

Age of the Sarikol Shales.

On the left side of the Shindi valley which runs from the Lakhshakh pass down to the Aksu, Stoliczka referred to another valley which comes in from the south-east at a little way above the mouth of the Shindi. This valley is known as the Kekchaki or, alternatively, as the Kakcheki, and is about 10 or 12 miles long.

Jurassic of Kekchaki valley.

At its mouth it runs across the strike of the Pamir limestone and underlying shales, which on the left side of the Shindi valley have a steady south-westerly dip. A few miles above its mouth the course of the Kekchaki valley is north-westerly and parallel to the strike of the limestone, the total thickness of which in the ridge between the Shindi and Kekchaki valleys is probably over 2,000 feet. The valley is fairly wide and for some miles above its mouth is full of glacial deposits. At about six miles up, the first outcrop of solid rock on the right bank of the river forms a small hillock in the centre of the valley. It is composed of a hard grey siliceous limestone weathering brown; it is thin-bedded and broken up by joints into small cuboidal fragments. This limestone contains crushed and rather badly preserved ammonites (*Perisphinctes*). About two miles higher up the valley a small stream known as Karakul-ashu comes in on the left bank. At a short distance above its mouth this stream splits into two branches, in the more northerly of which there is a fine section of the ammonite beds.



a. Sarikol Shales
b. Thin-bedded limestone at base of Pamir Limestone
c. Pamir Limestone
d. Perisphinctes horizon

FIG. 2. *Section across the Kekchaki valley.*

They have been considerably folded, and lie in a sharp synclinal of which the more southerly limb is almost vertical in places. The limestone stands up in great slabs, the surfaces of which are covered with ammonites; the latter consist chiefly of *Perisphinctes* most of which would probably have formerly been referred to the comprehensive form *Per. polyplocus* Rein.; the work of later authors such as Choffat, Siemiradski and others, has resulted in the restriction of that species within narrow limits and my collection comprises several species, but I have not been able to examine it minutely enough to say what they are; the material is not very well preserved and so many sub-genera and species have been created by Continental palæontologists under this genus that the points of difference are so minute as to make complete determination possible only in the case of specimens that are perfectly preserved not only as regards shape and surface ornamentation of both inner and outer whorls but also in respect of the suture line, more particularly in the umbilical region. A cursory examination of my material suggests the presence of forms allied to *P. frequens* Opp. and also to *P. Lothari* Opp., though I doubt if either species is actually present. Other specimens from the same bed appear to belong to the genera *Oppelia* and *Reineckia*; the latter determination is uncertain since the ventral area is not visible on either of my specimens; one of them, however, exactly resembles Steinmann's figure of his *R. Brancoi.* [1] I regard the general facies of the fauna as Callovian.

Cretaceous of Kekchaki valley.

At the head of the Kekchaki valley the Perisphinctes limestone is overlain by massive limestone followed by thin-bedded limestone and oolite. The latter beds are often composed to a great extent of spines and other fragments of echinoids, and contain also brachiopods, oysters and calcareous algae; all, however, are very badly preserved, and I found nothing definitely determinable. The beds are probably the same as those noticed at the top of the Pamir Limestone in the hills opposite Ujadbai in the Taghdumbash Pamir, and which I have referred to the Cretaceous system.

On the whole, the sections in the Shindi, Kekchaki and Khanjuli valleys seem to be the most promising in that part of the Russian Pamirs, and a detailed examination of them would no doubt result in the discovery of other fossiliferous horizons, though it must be admitted that, on the whole, the sedimentary rocks of the Russian Pamirs are disappointing in this respect.

Age and distribution of the Pamir Limestone.

As one stands on the top of the Lakhshakh pass and looks westward, one is surprised to see none of the broad open valleys that one has pictured as being characteristic of the Pamirs. Instead of these nothing is to be seen but a broken mass of rugged mountains terminating in the far distance in snow-capped peaks. The nearer mountains which are immediately across the valley of the Aksu, separate that valley from the Great and Alichur Pamirs. They consist of great masses of the limestone that I have called

[1] *Neues Jahrbuch,* Beilageband I, 285 (1881).

the Pamir Limestone, which runs approximately north-westwards through Istik and across the eastern end of the Alichur Pamir into the Bazar-dara range, beyond which I was unable to follow it; but it presumably runs thence westward along the Murghab valley. I found it again with the underlying slate series on the south of the Rang-kul Pamir, whence it runs almost due west into the Muskol mountains on the south of the Ak Baital valley. Stoliczka, who, on his return journey from Kala Panja and the Great Pamir, travelled down the Istik valley, regarded part of this limestone mass as Carboniferous, and it is possible that I have in places included in the Pamir Limestone a lower limestone which underlies part at least of the shale series. The absence of fossils, and the intense folding to which all the rocks in the Pamirs have been subjected, make it impossible to correlate with any confidence limestone masses which appear to be lithologically identical. At the same time I found near the mouth of the Kekchaki valley a small well-rounded fragment of Fusulina limestone probably derived from an old moraine. This fragment may have, and probably had, travelled some distance, for the same moraines are full of blocks of granite, a rock not found *in situ* in the Kekchaki valley, the boulders having evidently been brought to their present positions when glaciers extended across the hills which now form the divides between the drainage of the Murghab and the Karachukar rivers.

The Wakhan Slates.

To the south of the main limestone belt the underlying Wakhan slates extend throughout the Great and Little Pamirs and, as already mentioned, into the Karachukar valley of the Taghdumbash Pamir; along the Nicholas (Wakhan) range, which separates the Great Pamir from Wakhan, they are full of intrusive granite, but the series on the whole is one of slate rather than of more metamorphosed rock. There is, however, no sign of the black needle-shales characteristic of what I believe to be the same series on the opposite side of the belt of Pamir Limestone. At first, indeed, I did not correlate this great slate series of the Southern Pamirs with the Sarikol Shales. I had seen them originally as I looked across the Ab-i-Panja from the Baroghil and Shawitakh passes, whence all the mountains to the north of the river appear to consist of the same black slates. I met them again to the north of the Mintaka pass, and finally confirmed my observations by examining the Nicholas range in detail from the Urtabel pass to Concord peak. As in the

Karachukar valley, so also in the Great Pamir and the Nicholas range, the series is one of slate and quartzite full of igneous rocks, which sometimes appear to be interbedded and sometimes to be intrusive in the slates. I have not found the igneous rocks in the Pamir Limestone except quite at its base and I am, therefore, disposed to regard them as not much younger than the slate series. Associated with the slate there is, in addition to quartzite, a certain amount of limestone, sometimes dark and flaggy and resembling that interbedded with the slate and shale below the Pamir Limestone at Nezatash in Chinese Turkestan. This may correspond to the crystalline limestone seen in the upper Karachukar valley in the Taghdumbash Pamir. In the latter area, however, it is more highly metamorphosed. What is probably the same limestone equally metamorphosed is found again in the various valleys on the northern slopes of the Nicholas range. It is conspicuous at the mouth of the Urtabel valley at Salangur. It is found again at the mouth of the Sarikoram valley to the south-south-east of Karadung lake, where altered flaggy limestones, associated with black and dark-grey calcareous slates and calc-schists, are seen dipping to the south. Similar beds are found in the hills between the Sarikoram and Chilab valleys. In the latter valley blocks of a crushed limestone-conglomerate, and an equally crushed red pebbly sandstone were observed in both its main branches. The rock was not seen *in situ*, but it presumably occurs in the ridge between the main valley and its western branch. At the head of the latter branch, dark-grey slaty limestone was found *in situ* associated with dark schistose slates.

Wakhan Slates altered representatives of Sarikol Shales.

The general characters of the Wakhan Slates suggest that they are merely the metamorphosed representatives of the Sarikol Shales, which, like the slates, underlie the Pamir limestone. I have already described the shales as they occur in Chitral and in the Shindi valley. A dark flaggy Limestone, which occurs in them at Nezatash a few miles above Kengshubar, is probably the same as the limestone associated with the slates in the Nicholas range. A limestone, which may also be the same, was found associated with the Sarikol Shales at the mouth of the Pislang valley opposite Dafdar in the Taghdumbash Pamir. When I visited that valley, however, I was inclined to regard it—I now think incorrectly—as an infolded outlier of the Pamir Limestone.

Evidence that the Wakhan Slates are the altered representatives of the Sarikol Shales is found on the northern slopes of the Pamir range. That range, which separates the Great Pamir from the Alichur Pamir, consists for the greater part of granite, which has been intruded into, and has in many places absorbed, the slate series. Throughout almost its whole extent, the range is composed of muscovite-biotite granite and veins of pegmatite often containing crystals of muscovite as much as 4 or 5 inches across. The remains of the sedimentary series are to be seen in the form of gneiss and occasional bands of hornblendic schists, but in the centre of the range these are comparatively rare. They are more conspicuous, however, on its northern flanks. On the east and north-east of this massif the granite passes outwards through schists and slates, which again speedily give place in the Gurumdi and associated valleys—such as Urta-uch-kol, Kul-uch-kol, and Keng-shubar-uch-kol—to the typical Sarikol Shales underlying the Pamir Limestone. From this area the Sarikol Shales ought to pass into the Wakhan Slate series horizontally in the neighbourhood of the Kujigit pass. I was unable to confirm this by visiting that particular point, but I do not think there is any doubt about the continuation of the one set of beds into the other. On my rough sketch map, therefore, I have included both series in the same division.

Pamir Limestone between Aktash and Murghabi (Post Pamirski).

As one looks northward from Aktash, the country on either side of the Murghab river appears to be composed chiefly of the Sarikol Shales and associated igneous beds. I did not visit that part of the Pamirs, and only had a distant view of it from Aktash and again to some extent from the hills to the south of Murghabi (Post Pamirski), which also overlook the Aksu valley towards the east. All the great mass of irregular hills between Aktash and the Sarez Pamir consists of the Pamir Limestone, with the Sarikol Shales exposed in the intervening valleys.

Perisphinctes beds on Ayujuli pass and at Karasu.

Fossils similar to those of the Perisphinctes horizon of the Kekchaki valley, but fragmentary and badly preserved, were found about three miles west of the Ayujuli Kotal (pass), on the way from Aktash to Salangur, and again at Karasu on the main road from the Alichur Pamir to Post Pamirski. At the latter locality the fossils occur in dark thin-bedded limestones on the ridge on the right bank of the river just below Karasu post. At both these places the fossils observed were impressions and fragmentary remains of the *Perisphinctes* so characteristic of the Kekchaki beds.

Belemnite beds of Kengshubar-uch-kol.

In the Gurumdi and associated valleys, to which I have referred above, there are good exposures of the Pamir Limestone and underlying shales. On the right side of the main valley opposite Keng-shubar-uch-kol, the section consists of shale and sandstone—the typical Sarikol Shales—passing up through conglomerate into hard compact massive dark limestone full of calcite veins. Some of the bands of this limestone weather red. Above the massive limestone, which is about 500 feet thick, are well-bedded limestones, dark-grey, very hard and in places oolitic; they occur in beds of one foot or so in thickness. Above these is calcareous shale, very crushed and often slaty. Higher beds were not observed on this section, the uppermost beds of calcareous shale being faulted down against the lower shale and sandstone series. The beds are considerably disturbed, and intrusions of mica-lamprophyre (minette) are not uncommon. The only part of the section in which I found fossils was the uppermost band of calcareous shale which contains very crushed and badly preserved belemnites; these are rare and fragmentary and are composed of white crystalline calcite. Unfortunately I did not find the Perisphinctes horizon in this section, and I was unable to ascertain to what part of the Kekchaki section the belemnite bed ought to be referred, but as I found a fragment of a belemnite in some shaly beds in the upper part of the Perisphinctes beds in the latter valley, I am disposed to refer the Belemnite shales to that horizon.

Limestone and shale between Pamir range and Murghabi.

From Gurumdi I went due north across the Yangi-dawan to Mamazair-bulak and Nezatash which is on the main road through the Pamirs from Post Pamirski to the Alichur Pamir. This took me directly across the strike of the beds, which is here E-W. The rocks consist almost entirely of Pamir Limestone along the ridges, and slates and shales in the valleys. There is the usual dearth of fossils throughout. From Nezatash, which is not to be confused with the place of the same name in Chinese Turkestan, the main road runs through a gorge bounded on either side by immense cliffs of folded and contorted beds of the Pamir Limestone. As the road issues from the gorge, the valley widens and is filled with bright-red horizontal beds of false-bedded gravels. At Karasu post, as already stated, the upper part of the Pamir Limestone is exposed in the hills on the right side of the valley, where limestones, associated with shales, yielded impressions of *Perisphinctes.* From a distance there appears to be a good section of the whole sequence from the Sarikol Shales up through the Pamir Limestone in the high and conspicuous hill about five miles to the east ot Karasu. At the northern end of the hill the beds appear to be horizontal, but bend over with a steep dip on the south.

Metamorphism at Murghabi.

From Karasu to Murghabi the Pamir Limestone and the underlying shale series continue all the way. As the Murghab river is approached, metamorphism becomes pronounced, the limestones become calc-schists, the shales slates, and the series rapidly assumes a thoroughly metamorphic aspect.

To the north of Post Pamirski my observations are even more incomplete than on the south, since from that point I was travelling more rapidly,—on an average about 30 miles a day. On the main road from Murghabi to Ak Baital post, rock is first met with in the Ak Baital valley at about 4 miles from the Murghab river. It consists of conglomerate and sandstone associated with a zeolitic trap, and forms part of a thick series which continues for about two miles up the Ak Baital valley. It is much contorted, and is associated with a series of slate and quartzite and with gneiss and crystalline limestone, the last-named rock being exposed at the point where the road from Rang-kul enters the Ak Baital valley. The slate and quartzite series contains intrusions of basic igneous rock, and is possibly the altered representative of the Sarikol Shales. I did not recognise the thick conglomerate series, but it may represent the beds associated in Kizil jilgha with the Sarikol Shales; the series seems to have been considerably metamorphosed in places, for blocks of schistose and gneissose conglomerate are brought down by the subsidiary streams flowing into the Ak Baital valley. In the main valley, however, the conglomerate is not altered, and is associated with soft false-bedded sandstones and pebbly beds. It is possible, therefore, that there are two conglomerate series

Rocks of the Ak Baital valley.

in this area—an older and a younger. Where first observed *in situ,* the conglomerate is found in association with a zeolitic trap, similar to that intrusive in the slates above Nezatash in Chinese Turkestan.

The rocks of the Ak Baital valley above the post of the same name consist, first of all, of a slate series and subsequently of limestones. About 10 versts above Ak Baital post a hill on the right side of the road (left side of the valley) is composed of a dark-green igneous rock below with limestone above, and these probably represent the Pamir Limestone and underlying slate series. At verst 14 a ridge running down into the valley is composed of grey brecciated limestone, and the hills on the right (south) side of the valley are composed of a limestone which appears to be the Pamir Limestone. At verst 19 the road to the Ak Baital pass leaves the river-bed for a short distance, and at this point there is on the left bank of the river a small projecting headland of dark-grey limestone, which is compact and hard, and contains veins of calcite. It dips at high angles (50° to 60°) to SSE, its strike bring ENE-WSW. The limestone is immediately underlain by carbonaceous shale with thin courses of limestone and occasional bands of sandstone. Both limestone and sandstone courses are full of brachiopods over a thickness of between 60 and 70 feet; the fossils include *Spirifer Verneuili* Murch., *Productella subaculeata* Murch., *Strophalosia productoides* Murch. and many *Rhynchonellidæ* and corals; they are evidently of Upper Devonian age. These fossiliferous beds are underlain by coarsely pisolitic limestones containing small *Rhynchonellidæ* and associated with hard compact limestones containing silicified corals.

Devonian below Ak Baital pass.

The Upper Devonian limestone seems to pass up into a mass of broken limestone, shale, sandstone, and finally into a conglomerate, all of which weather in brilliant colours, including red, yellow, grey and black. Associated with these beds are dark igneous rocks (diabase) and much gypsum. To the south of the pass the high hills appear to be composed of Pamir Limestone underlain by the conglomerate already referred to. The latter rock is seen in the stream on the way down from the pass at about verst 29, and the descent into the Muskol valley is strewn with blocks of conglomerate. The prevailing rocks on either side

Country between Ak Baital pass and Great Karakul.

of the Muskol valley down to the post of the same name are slates, often carbonaceous. I had hoped to determine the relative position of this series with regard to the Devonian limestones of Ak Baital, but a snowstorm rendered geological work impossible for nearly a week, and my observations in this part of the country were confined to such isolated masses of rock as happened to be too steep for snow to lie on. From Muskol post I made a rapid traverse as far as Great Karakul and back. Such rocks as I could see on the road were slate and limestone, more or less metamorphosed and often replaced by schist and calc-schist. The high ridge which runs out into the lake from the southern shore, consists of granite at its northern end.

From Muskol to Rangkul.

From Muskol I travelled east over the Kizil-jiyik pass *viâ* Chal Mirza Rabat to Rang-kul. The country was unfortunately still under snow, and rocks were rarely visible. Here and there I found schists, slates, metamorphosed limestones, and a crushed conglomerate. Near the western foot of the Kizil-jiyik pass, beds of conglomerate and sandstone are found dipping to NE. They dip at quite low angles, and are not much crushed or disturbed. The conglomerate series weathers to a brilliant red and extends across the pass and down to Chal Mirza Rabat, where it forms the cliffs on the left bank of the stream; it contains pebbles of oolitic and coral limestone, which are almost certainly derived from the upper beds of the Pamir Limestone. At Chal Mirza Rabat it is faulted against a series of thin flaggy crystalline limestone and black carbonaceous shale, the shale being similar in appearance to the Devonian shale of Ak Baital but quite unfossiliferous here. The conglomerate series is perhaps Tertiary. It is not unlike the Ak Baital conglomerate, the apparent relationship of which to the Devonian and to the supposed Pamir Limestone of that locality may have been wrongly inferred by me since I crossed the pass in the dusk and during a snowstorm, and my observations were therefore hurried, and imperfect. It is possible that the Ak Baital pass lies on a line of important faulting (*infra* p. 317).

From Chal Mirza Rabat eastwards the road to Rang-kul crosses an open gravel-strewn valley, and no rock is found *in situ* until one reaches the hill at the foot of the Ishi pass, which consists of hard, dark, brown-weathering crystalline limestone overlying grey and black carbonaceous shale. Further to the east reddish-brown limestones in thin flaggy bands and very thin pebbly beds are interbedded with black carbonaceous shale. These beds continue to the east across the Tusdün Beles (pass), and are well exposed along the left side of the small valley leading eastwards down to the Rang-kul plain. About three miles below the pass a bed of rock-salt is seen under some sub-recent river sands and gravels. This has already been referred to by D. L. Ivanow in his account of his exploration of the Pamirs. As mentioned by him, the deposit is small and apparently of no economic importance; it seems to be exploited to a small extent, but only in quite a superficial manner. The age of the carbonaceous slate series could no doubt be determined by careful examination of the country between the Ak Baital and Kizil-jiyik passes, for the Upper Devonian supplies a known horizon from which to work. In general appearance the carbonaceous beds resemble the Angara series, but this lithological resemblance has already been found to be so misleading in the Pamirs that I attach no importance to it. The carbonaceous shales seen between the Kizil-jiyik and Rang-kul are equally like the shales associated with the Devonian of Ak Baital.

Pamir Limestone and Sarikol Shales at Rang-kul.

On the southern side of the Rang-kul plain massive grey limestone forms a high and conspicuous ridge running approximately E-W. At the edge of the plain the grey and black carbonaceous shale series, which is here altered into slate and sometimes into phyllite, contains thin bands of reddish-brown limestone, and dips to the south, apparently under the massive limestone. The shale series is so altered as rarely to contain any fossils. A few fragmentary specimens were found, but were not determinable. The junction of this shale series with the massive limestone was not seen, being everywhere covered by scree, but it appears to be a fault, since everywhere in the neighbourhood of the junction the surface is covered with blocks of limestone breccia, similar to that seen at verst 14 in the Ak Baital valley. Hence it is possible that an important fault runs along the southern side of the Rang-kul Pamir and up the Ak Baital valley. The massive limestone, however, which forms high cliffs, appears to be identical with the typical Pamir Limestone, and the underlying carbonaceous series may be a local development of the Sarikol Shales.

From Rang-kul *viâ* Haramut to Muji.

To the north-east of Rang-kul the hills separating the Russian Pamirs from the Muji valley of Chinese Turkestan consist of the carbonaceous slate series on the south-west, passing up into shaly and schistose limestones followed by calc-schists, which extend almost up to the Haramut pass. On the pass itself the rock is a hard dark-grey limestone, which gives place on the north of the pass to granite. The latter rock predominates throughout the Haramut valley, and extends on to the junction of the Karazak and Muji valleys, where the prevailing rock is slate full of granite intrusions.

The Muji valley a Pamir.

The Muji valley itself is a typical Pamir. It is bounded on the north and north-east by the Kashgar range, which consists of a striking series of sharp peaks, all of very much the same height with intervening hanging glaciers. In its westerly portions the Kashgar range appears to be merely a continuation of the Trans-Alai mountains; it consists of metamorphic rocks including carbonaceous slate, crystalline limestone and hornblendic schist. The strike of these rocks is approximately E-W, and along the northern side of the Muji valley the range is a true tectonic feature. At the peak marked on Curzon's map Bulun-sunin-tau at the head of the King-su valley, most maps show the range as turning to south or south-east. To the south of this point the range is no longer a tectonic one, but consists merely of a mountain mass in which the strike of the rocks still continues to be approximately E-W. The origin of this part of the range—if range it can be called—seems to be due to the presence of the great granite massifs to the south, the intrusion of which has resulted in greater elevation of the neighbouring areas and at the same time in the induration of their component rocks. The Muji river, from its source to the King-su valley, originally carved out its course along an anticline, still visible in the latter valley which lies on its axis. The course of the Muji river now lies to the south of the anticlinal crest, its displacement being due probably to the immense fans and moraines carried into the valley from the southern slopes of the Kashgar range. These have pushed the river southwards and have forced it to cut into the southerly-dipping slates of the Gurumdi hill-mass.

From Muji I travelled eastward across the Ulug-art (pass). The rocks of the Ulug-art valley consist of slate, sandstone, grit,

The Kashgar range and Ulug-art.

conglomerate and limestone, all very much crushed and schistose and usually metamorphosed. The strike is still easterly and the dip to the north, both in the Ulug-art and in the neighbouring Tuyuk-tar valleys. In the higher peaks granite occurs in some quantity. The pass itself (Ulug-art) lies on slate and quartzite, while the hills surrounding it consist partly of white crystalline limestone like that of the Kashgar range to the north of Muji. To the east of the pass the strike of the rocks is still easterly, and continues thus all the way down to the Kashgar plain. The existing maps of the mountains between Muji and Kashgar are incomplete, nor, so far as they go, are they accurate. They show a continuous range with a clearly-defined narrow culminating ridge, which does not in reality exist. Actually there is a broad mountain-mass of approximately the same height over a width from east to west of 10 or 15 miles and into this the streams have cut back their courses, largely following the strike of the component rocks. This part of the so-called Kashgar range, in fact, appears to be a broad mass of highly folded and metamorphosed sediments compressed against the great granite massif to the south.

To the east of the Ulug-art (pass) there is a steep descent to Saraktash, whence the valley first crosses the strike of the rocks for about four miles, and then follows it almost continuously all the way to Jolchi-mainak. The rocks seen are all metamorphic, consisting of schists, slate and quartzites. At Jolchi-mainak a dark-grey more or less crystalline limestone forms high cliffs on the left side of the valley. Similar rocks continue all the way to the gravel fans which slope down from the mountains to the Kashgar plain. The last outcrop of rock seen between Jolchi-mainak and Juluk-bash is a small inlier of dark-grey limestone similar to that of Jolchi-mainak. It occurs on the left bank and in the bed of the valley about 3 miles from the point at which the river leaves the mountains. It is practically horizontal, with perhaps a slight dip towards the hills.

Ulug-art to Kashgar.

4. Kashgar and the Alai.

Between Kashgar and Russian Turkestan my route lay over country that has already been traversed by other geologists, and I did not attempt, therefore, to make any detailed observations. Up to the Russian frontier at Irkeshtam, the road lies almost entirely on the Ferghana series, which is often full of excellent fossils, especially from Kushuga onwards. I also noticed coal-bearing beds, which, no doubt, were the true Angara series. Beyond Irkeshtam the road to Osh *viâ* the Terek-dawan passes on to older rocks resembling those of the Pamirs, and I met with Fusulina limestone at about one mile beyond the Koksu ford.

Fusulina limestone in Koksu.

During my stay in Kashgar, Sir George Macartney kindly made over to me a collection of fossils which had for some time been lying in the Residency. These consisted of *Ostrea turkestanensis* Rom. said to have been brought from Tashmalik (Tashbulak) near the eastern end of the Gez defile and about 40 miles south-west of Kashgar. So far as I can ascertain, this locality was not visited by Stoliczka, but the oysters no doubt came from his Artysh beds, which represent the Ferghana series of Russian Turkestan. Coal is also to be found in the neighbourhood of Tashmalik, the occurrence being indicated on von Schultz' map of the Pamirs. This seems to point to the presence of the Angara series.

Ferghana series in Chinese Turkestan.

5. Summary of Stratigraphical and Tectonic Results.

From the above notes, uncertain and imperfect as they are, it will be seen that the general distribution of the stratigraphical groups between India and Russian Turkestan consists of, first of all, a belt of igneous and metamorphic rocks running through the outer mountains of Dir and Swat and continuing to the east across the Indus and perhaps into Hazara. To the west the igneous and metamorphic rocks of the Kabul river below Jalalabad probably belong to the same group. Between Dir and Chitral granite prevails, but to the north of the Laorai pass, which crosses the granite belt, a group of sediments, including beds at least as old as Devonian on the one hand and as young as Cretaceous on the other, extends throughout Chitral and into Yasin and Hunza. To the north of this again we meet with a great belt of slates extending from the Wakhan (Nicholas) range into the Taghdumbash Pamir of Chinese Turkestan, and followed still further to the north by a calcareous group, which is the most prominent feature of the Russian Pamirs and which I have named, for the sake of convenience, the Pamir Limestone. To the north of this, again, is a belt

Main stratigraphical tones.

of carbonaceous slates. probably in part representatives of the Wakhan slates but associated with shales and limestones containing Upper Devonian fossils. Beyond this, again, in the valley of the Kizil-su there is a typical development of the Ferghana series.

Hindu Kush and Pamir ranges true tectonic features.

Each of these stratigraphical groups constitutes a belt which can be traced over a very considerable distance and which follows in the main the trend of the more important mountain ranges. Thus the general strike of the rocks in western Chitral is SW-NE, following the trend of the Hindu Kush. In Upper Chitral this direction gradually bends round to W-E. Similarly, throughout the Pamirs, as already noticed by Ivanow, the strike is almost consistently approximately E-W. On either side of the Pamirs, the strike bends away towards the south, being NE-SW on the west and NW-SE on the east. In fact, the strike of the rocks, as well as the trend of the mountain ranges, follows in the main the outline of the great re-entrant bay of the Himalayan mountain foot between the longitudes of 70° and 77°. As might be expected, this feature is reflected in the hinterland of the Himalayan system represented by the Hindu Kush, the Karakoram and other mountain ranges of Kashmir. The main ranges are therefore true tectonic features.

Relationship of Afghanistan to the Himalaya.

It is possible now to make some attempt to indicate the relationship between the fossiliferous basins of the North-Western Himalaya and those of the Hindu Kush and Afghanistan. Although our knowledge of the Palæozoic group both in Afghanistan and in Chitral is very imperfect, yet the resemblance between its component elements in those two areas respectively is such that there can be no reasonable doubt that the Palæozoic group of Chitral is merely the continuation of that of the mountains on either side of Bamian. One would, in fact, expect the fossiliferous Palæozoic beds to be continuous from one area into the other through Kafiristan. Through Chitral this belt runs first north-east then practically due east into Hunza, after which it probably bends round into the great mountain masses of Baltistan, passing perhaps onwards into the neighbourhood of Leh and Chang-chenmo, and thus remaining outside the main Himalayan basin as represented by Spiti, Garhwal and Kumaun. The latter basin finds its continuation, as we know, in the mountains round Srinagar, whence it probably passes westward, and is either obliterated by metamorphism and igneous action or is hidden under the younger Tertiary deposits of the North-West Frontier Province and the Punjab. Beyond the Chitral fossiliferous belt is that of the Wakhan Slates and Pamir Limestone. These follow the same trend as the inner belt. The Pamir Limestone is found in the south-eastern corner of the Pamirs; striking to the south-east, it forms the southern part of what is usually called the Sarikol range and runs across *the right-angled bend in the Karachukar river.* It ought, therefore, to run through Raskam pass towards the Karakoram range and Lingzi-tang. Owing to the great breadth of the zone of Pamir Limestone and Wakhan Slates in the Pamirs, one would expect it to extend beyond Raskam, and it is probable that the same zone will be found also in the Kuenlun.

The Sarikol and Kashgar ranges.

It has hitherto been customary for both geographers and geologists to regard the Pamirs as bounded on the east by two meridional ranges known as the Sarikol and the Kashgar ranges and separated from one another by the Tagharma valley and its southerly continuation, the Taghdumbash Pamir. It has been assumed that these two ranges are true tectonic features and indicate a local and hitherto unexplained irregularity in the distribution of the structural trend-lines of Asia. So firmly has this impression been established that Suess has even gone so far as to say that "Stoliczka was mistaken in thinking that the Trias limestone of Aktash in the Pamir is continued towards the south-east into the fossiliferous limestones of the Kárákorum district"; and he goes on to add: "We perceive, on the contrary, that the masses of gneiss which Stoliczka crossed between Balgun, Tashkurgan, and Kanshubar (east of Aktash) are not only continued towards the north into the Mustag-Ata, but in all likelihood also to the south, through the range of Taghdumbash to the high mountains of the Mustag."[1] Thus Suess indicates a great meridional belt of gneiss stretching from Mustagh-Ata down to the Hindu Kush between Hunza and Oprang. This is yet another instance of the danger of assuming Stoliczka to have been mistaken. I have followed the latter's work now in almost all the parts of Asia that he visited, and although, owing to circumstances beyond

Sarikol range a border range and not tectonic.

[1] The Face of the Earth, Vol. III, 273.

his control, it might have been at times incomplete, I have rarely if ever, met with an instance in which it was possible to say that it was wrong. In the present case he was right in assuming that the Pamir Limestone of Aktash was continued to the south-east; I found it in the Taghdumbash Pamir some fifty miles to the south-east of Aktash, and saw it running far into the distance in the same direction. How far it goes I am not in a position to say; it may no doubt be cut out here and there in the mountains of Raskam; it might be expected to lie to the north-east of the Karakoram range but the results of the explorations of Dr. Filippi's most recent expedition will probably throw much valuable light on the relationship between the Pamir geosynclinal basin and the sedimentary belt already recorded in the neighbourhood of K_2.[1]

Viewed from the Taghdumbash Pamir the Sarikol Range, which forms the eastern boundary of the Russian Pamirs, undoubtedly appears to be a true orographical feature; it is not, however, in any sense a tectonic element but is what Prince Kropotkin has called a border range.[2] In its southern part the strike is everywhere across the range, meeting it at angles of from 45° to 90°. In the continuation of the range to the north, between the Rang-kul Pamir and Little Karakul, the strike again appears to be approximately at right angles to the range; I was unable to confirm this observation at close quarters; but where I crossed the range to the north-east of the Rang-kul Pamir, it is still easterly. I have already pointed out that in the mountains still further to the north but along the same meridian (75°), the strike is still approximately E-W; hence the true structural lines of this part of Asia are not such as have been represented by Suess[3] and Fütterer.[4] The regularity of the trend-lines may perhaps not persist into the neighbourhood of, and to the south-east of, Mustagh-ata; Stoliczka's observations between Yangi Hissar and Tashkurghan, however, indicate a general NW—SE strike, and it seems probable that, except for partial and purely local irregularities due to the great intrusive granite masses of Kungur and Mustagh-ata, the general trend of the tectonic lines will be found to follow the curve indicated by the northern boundary of the Indo-Gangetic alluvium. The so-called Sarikol range, which is generally shown

[1] F. de Filippi: *Karakoram and Western Himalaya*, Appendix C (1912).
[2] *Geographical Journal*, XXIII (1904), 184.
[3] *The Face of the Earth* (English Translation), Vol. III, map.
[4] *Petermanns Mittheilungen*: Ergännzungsheft, No. 119 (1896) map.

as running almost N—S in the neighbourhood of longitude 75° and between latitudes 39° and 37°, might be regarded as the eroded scarp of the Pamir plateau, owing its greater elevation to the presence of intruded masses of granite of which the most striking relics are now the massifs of Mustagh-ata and Kungur which *lie on the line of the supposed southerly continuation of the Kashgar range.*

The Kashgar range only partly tectonic.

The latter range is shown on some maps as a single meridional element enclosing the Taghdumbash Pamir on the east and extending through the peaks of Mustagh-ata and Kungur; on others it is carried still further to the north and shown as continuous with the jagged snow-capped range which runs from west to east along the northern side of the Muji valley. It is thus shown as having anomalous right-angled bend at the peak named Bulun-sunin-tau on Curzon's map. I have already pointed out (page 318) that the range running from west to east along the northern side of the Muji valley is a true tectonic element, and corresponds in trend with the strike of its component rocks, and that the mountain mass which extends southwards from its eastern end to the Gez defile consists of a highly folded series of rocks altered by the granite of the Chak-kara-kul massif. The axes of the folds, however, are equatorial and not meridional. This mountain mass perhaps owes its existence to elevation and induration produced by the granite. Its westerly continuation is to be found in Mount Gurumdi and the mountainous region between the Karazak and Haramut valleys, from which it is separated by the Muji valley, the latter being first approximately parallel to, but subsequently cutting across, the strike. On the east the mountains rise abruptly from the Tarim basin, of which they form the western edge and which is usually regarded as an area of subsidence. Although, therefore, it may be convenient from the purely topographical point of view to regard Ulug-art, Kungur, Mustagh-ata and the hills on the east of the Taghdumbash Pamir as forming a continuous and approximately meridional mountain range, it is not permissible to infer therefrom that the feature thus constructed is a true tectonic element indicating the direction of the trend-lines of the folding of this part of Asia. Stoliczka's observations from Yangi Hissar to Tashkurghan reveal a marked regularity in the direction of strike, the dips recorded by him throughout being either to north-east or south-west with few exceptions; such exceptions occur in the neighbourhood of the intrusive rocks to the south-east of Mustagh-ata, where he found the direction of dip to be NNE. When he met with the more highly metamorphosed rocks and the granite between Mustagh-ata and Tashkurghan, the rocks were apparently too massive to show any clear strike of the foliation planes. That irregularities of strike will be found on the flanks of the great granite massifs in the west of Chinese Turkestan is only to be anticipated, and one might expect that the sediments into which these massifs have been intruded will show in their neighbourhood a disturbance of strike such as is found on a small scale round large crystals of felspar or other porphyritic minerals in a foliated gneiss. But from such observations as I have been able to make—only from some distance, I must admit, from the two great massifs,—it seems to me probable that the prevailing strike between the Pamirs and Kungur and Mustagh-ata will be found to be at first approximately W-E, and subsequently, on the flanks of the latter mountains, either south-easterly or perhaps even north-easterly. At present there is no evidence in favour of the anomalous trend-lines assumed by Suess and Fütterer to prevail in that region.

EXPLANATION OF PLATES.

PLATE 27.

FIG. 1.—Devonian in hills opposite Reshun, Chitral.
FIG. 2.—Devonian on Koragh spur, Chitral.

PLATE 28.

FIG. 1.—Folded conglomerate in valley behind Reshun.
FIG. 2.—Dasht-i-Baroghil and Sakez Jarab range from the Baroghil pass.

PLATE 29.

FIG. 1.—Slates and andesites in Karachukar valley, Taghdumbash Pamir.
FIG. 2.—The Russian Pamirs as seen from the top of the Lakhshakh pass.

PLATE 30.

FIG. 1.—Jurassic (Perisphinctes) beds at the head of the Kekchaki valley.
FIG. 2.—Kashgar range from near Muji.

PLATE 31.

FIG. 1.—Quartz-andesite with altered hornblende: from near mouth of Karakokti valley, Taghdumbash Pamir.

FIG. 2.—Dacite: from Reshun conglomerate at Awi, Chitral.

FIG. 3.—Andesite with altered apatite: from right side of Karachukar valley between Dastor and Sarik jilgha, Taghdumbash Pamir.

FIG. 4.—Orbitolina limestone: from Reshun conglomerate, 1½ mile below Reshun, Chitral.

q, quartz; *f*, felspar, *h*, hornblende;
g, groundmass; *c*, chlorite; *a*, apatite.

PLATE 32.

Geological sketch-map of Chitral and the Pamirs.

GEOGRAPHICAL INDEX.

	Latitude.		Longitude.		Page.
	°	′	°	′	
Dasht-i-Taus	36	23	73	20	295.
Dir	35	11	71	55	272, 275, 276, 320.
Drosh	35	34	71	50	272, 278, 279, 280, 285.
Dubarghar	36	42	72	58	289.
Duman	36	20	73	23	296.
Gahiret	35	40	71	49	281, 282.
Gakshi	36	42	73	28	294.
Galatak	35	32	71	48	280.
Gez	38	47	75	20	320.
Ghazar R.	36	10	73	10	296.
Gilgit	35	54	74	18	271, 294, 297.
Gircha	36	40	74	55	299.
Golen	35	57	72	1	282, 283, 287.
Great Kara-kul	39	0	73	30	316.
Great Pamir	37	25	73	40	293, 309, 310.
Gujar	35	20	71	52	277.
Gujhal	36	35	75	0	294, 298.
Gulmit	36	23	74	55	297.
Gupis	36	12	73	28	272, 296, 297.
Gurumdi Mt.	39	3	74	15	318, 324.
Gurumdi R.	37	43	73	55	312, 313.

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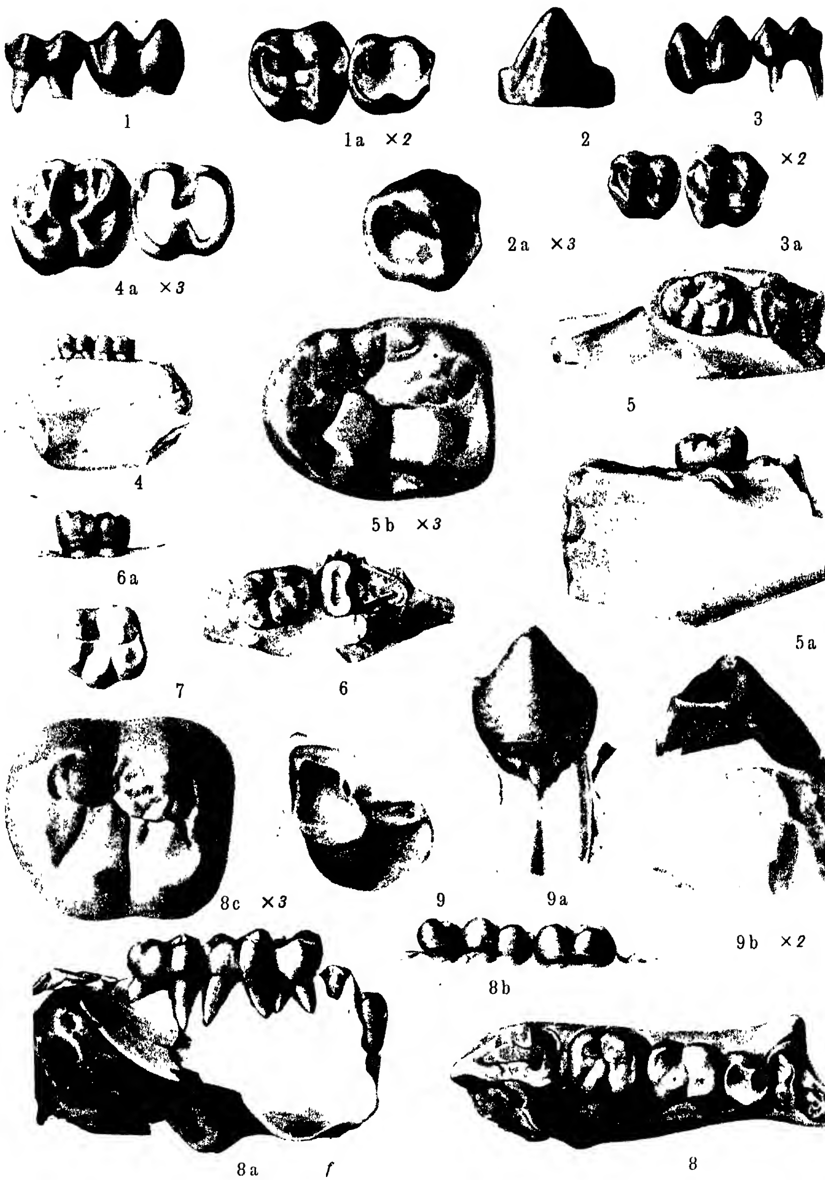
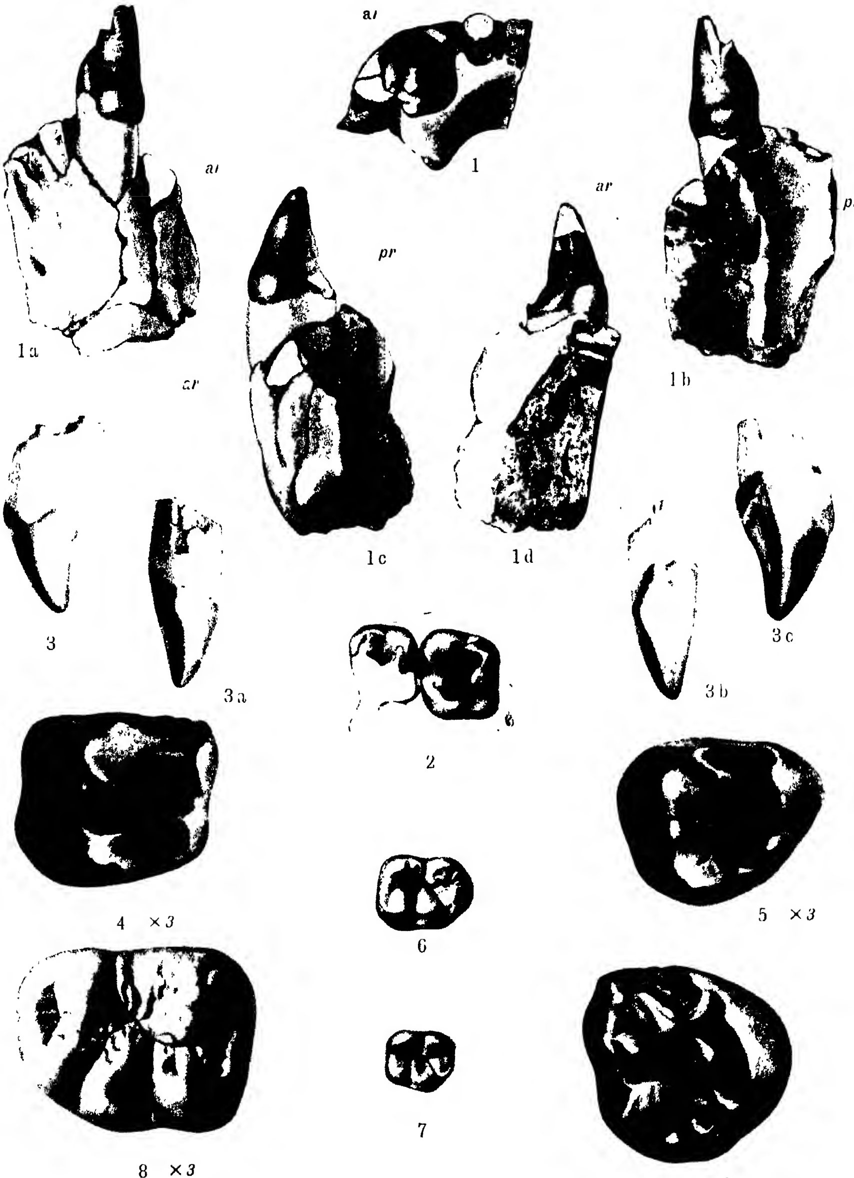


G. M. Woodward and S. N. Guine, del (Figs. 1—5) Figs. 6, 9a, 9b.)

G. S. I. Calcutta.

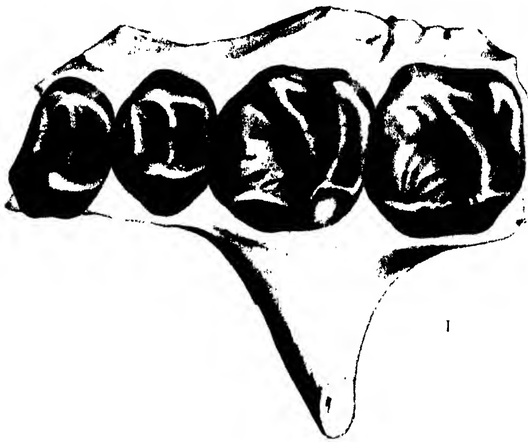
NEW SIWALIK PRIMATES.



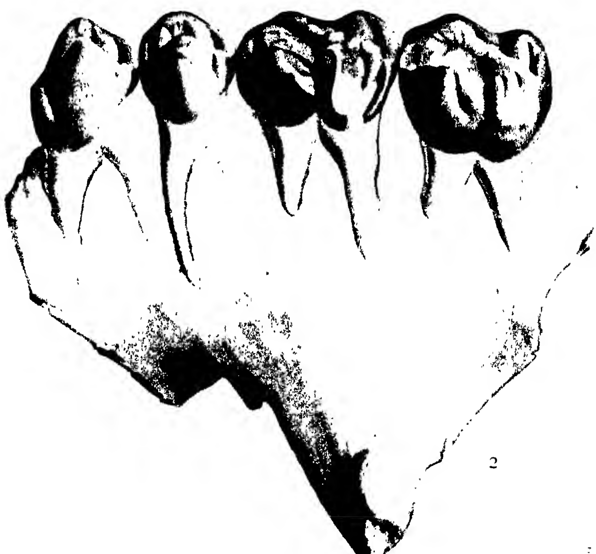
G. M. Woodward and S. N. Gunne, del. (Figs. 6—8) Figs. 1—5 & 9

NEW SIWALIK PRIMATES.

G. S. I. CALCUTTA.



1



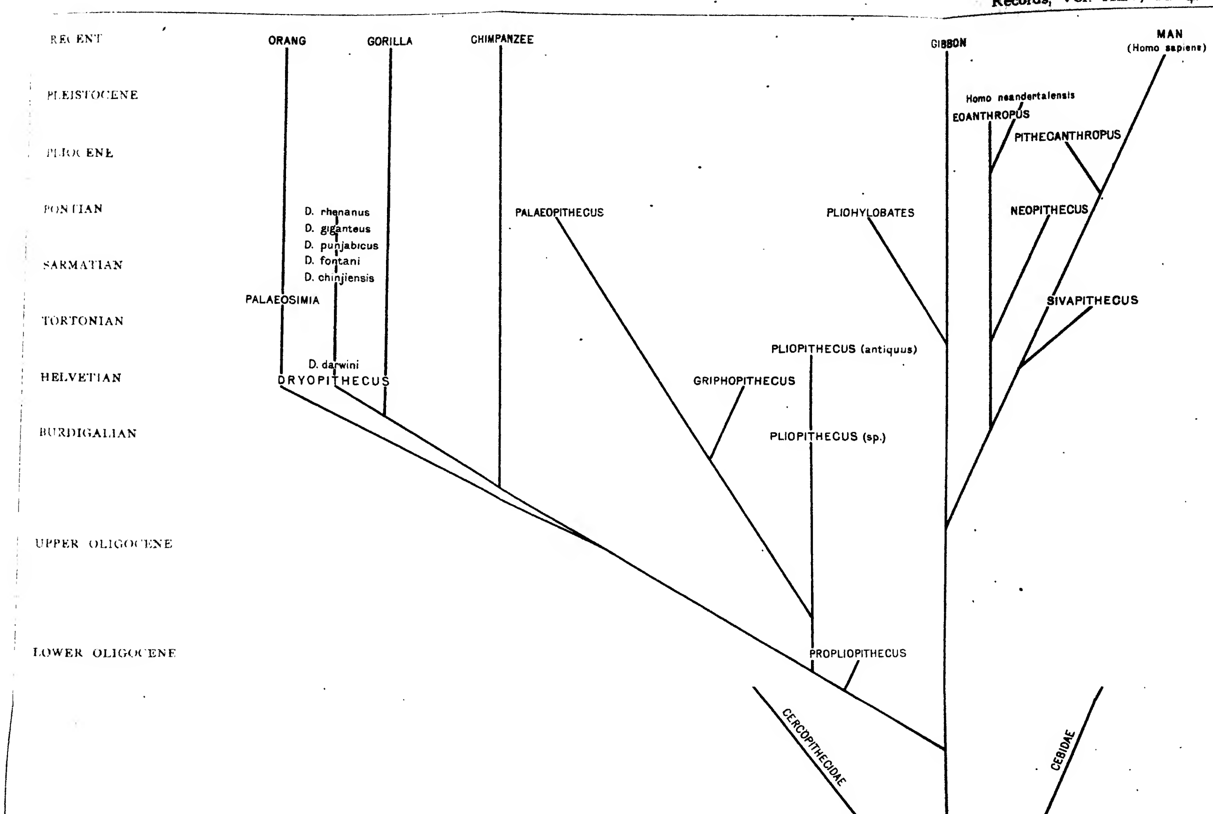
2

S. N. Guine, del.

G. S. I. Calcutta.

NEW SIWALIK PRIMATES.

(enlarged three times natural size.)



C. S. I. Calcutta.

SUGGESTED EVOLUTION of MAN and the ANTHROPOID APES.

fig. 1.

fig. 1a

fig. 2.

fig. 2a

G. S. I. CALCUTTA

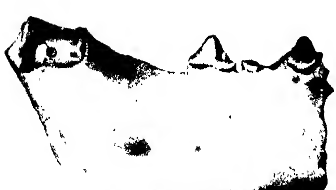
PARAMACHŒRODUS cf. SCHLOSSERI, *Weith.*

(all figures natural size.)

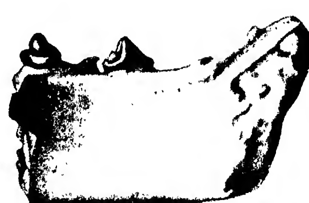
1

1a

2



2a



2b

G. S. I. Calcutta

SIVÆLURUS CHINJIENSIS *Pilg.*

Photo. K. F. Watkinson.

G. S. I. Calcutta.

THE KUTTIPPURAM METEORITE.

(Half natural size.)

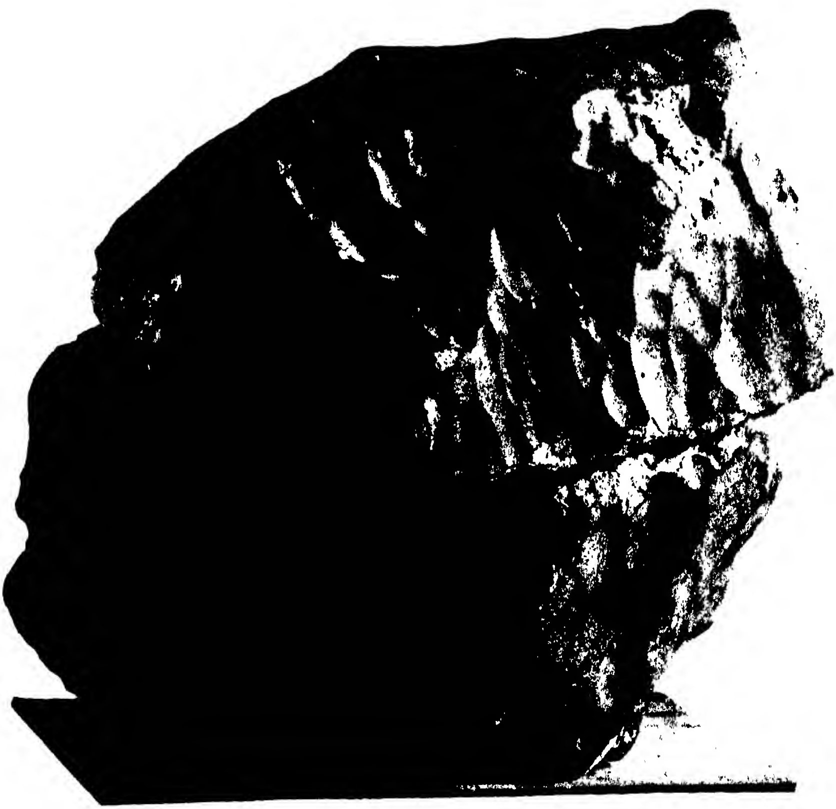


Photo. K. F. Watkinson.

G. S. I. Calcutta.

THE KUTTIPPURAM METEORITE.

(Half natural size.)

'hoto K. F. Watkinson. G. S. I. Calcutta.

THE KUTTIPPURAM METEORITE.

(Half natural size.)

oto K. F Watkinson. G. S. I. Calcutta.

THE KUTTIPPURAM METEORITE.

(Half natural size.)

Phcto. K. F. Watkinson. G. S. I. Calcutta.

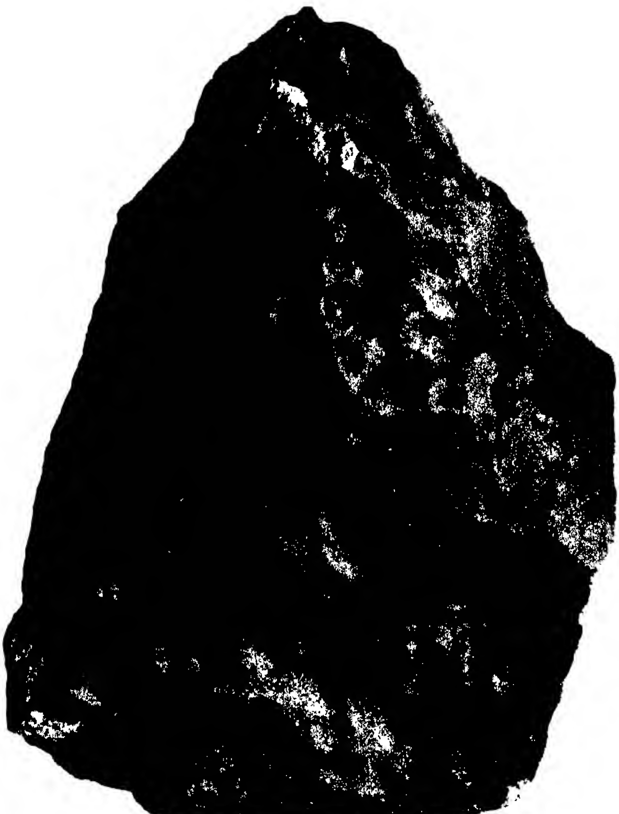
THE KUTTIPPURAM METEORITE.

(Half natural size.)

G. S. I. CALCUTTA.

THE KUTTIPPURAM METEORITE.

(Three-fourths natural size.)



G. S. I. CALCUTTA.

THE KUTTIPPURAM METEORITE.

(about two-thirds natural size.)

G. S. I. Calcutta

THE KUTTIPPURAM METEORITE,
small fragments
([illegible] natural size)

FIG. 1. THE GRANULAR GROUNDMASS OF THE KUTTIPPURAM METEORITE.

FIG. 2. CHONDRI IN THE KAMSAGAR METEORITE.

Photo. K. F. Watkinson.

G. S. I. Calcutta.

FIG. 3.

FIG 4.

THE INTRICATE VEIN SYSTEM OF THE KUTTIPPURAM METEORITE.

(all figs. X 20, approx.)

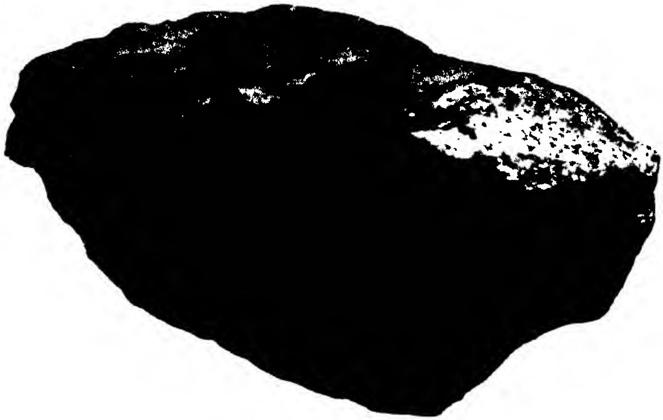


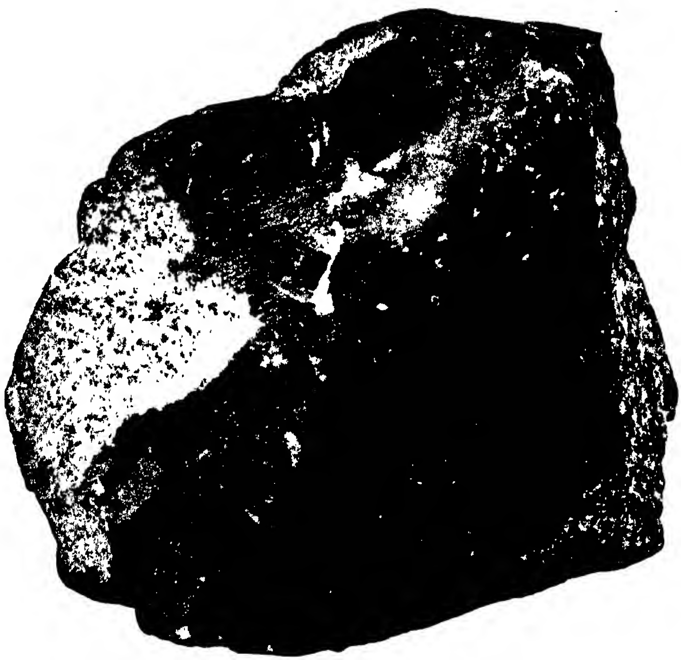
Fig. 1 THE SHUPIYAN METEORITE.
(natural size.)

G. S. I. Calcutta.

Fig. 2. THE KAMSAGAR METEORITE.
(about four-fifths natural size.)

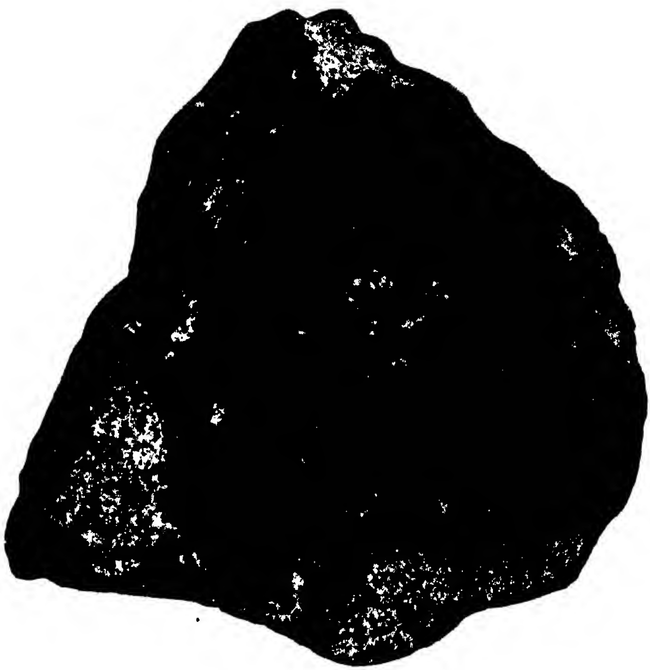
THE KAMSAGAR METEORITE.
(about four-fifths natural size.)

G. S. I. Calcutta



G. S. I. CALCUTTA.

THE SHUPIYAN METEORITE.
in the Srinagar Museum, Kashmir.
(about three-fifths natural size.)



G. S. I. CALCUTTA.

THE SHUPIYAN METEORITE.
In the Srinagar Museum, Kashmir.
(about three-fifths natural size.)

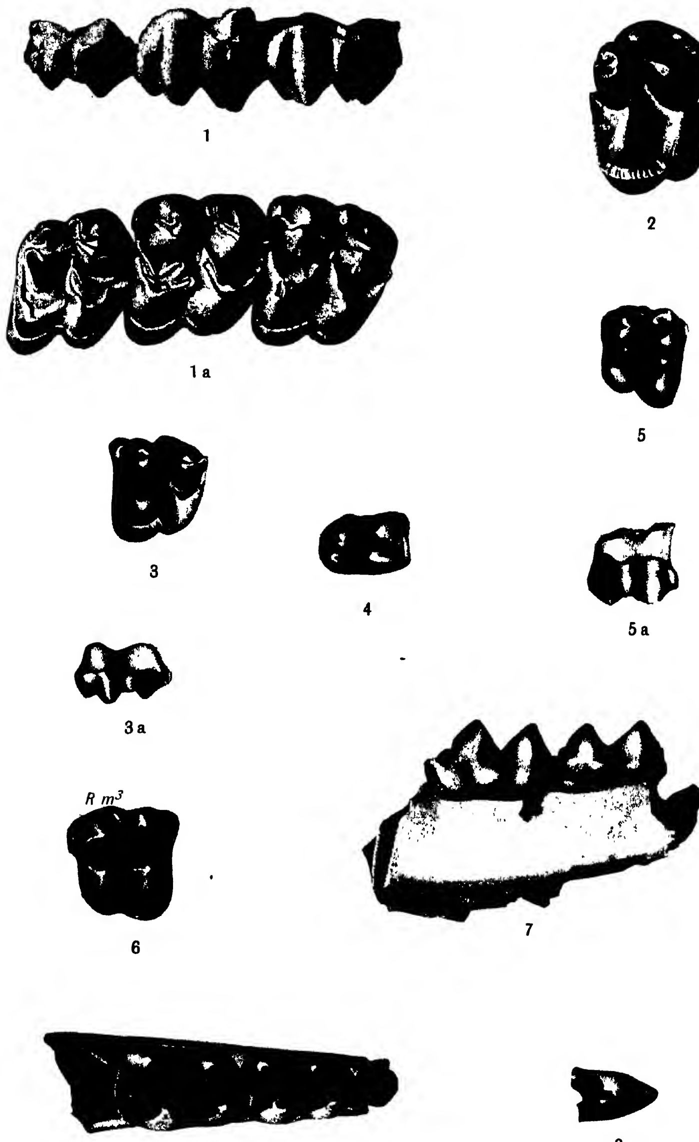
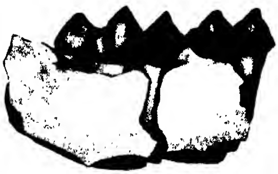


Fig. *1 - 2 by G. M. Woodward,*
,, 3 - 8 by S. N. Guine.

G. S. I. Calcutta.



1

1 a

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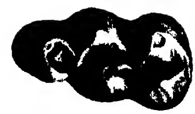

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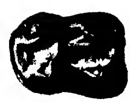
2 a

4 a



5

6

7

8

9

Fig. 2-5 & 7-9 by G. M. Woodward,

G. S. I. Calcutta.

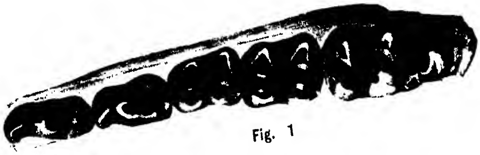


Fig. 1

Fig. 1 a

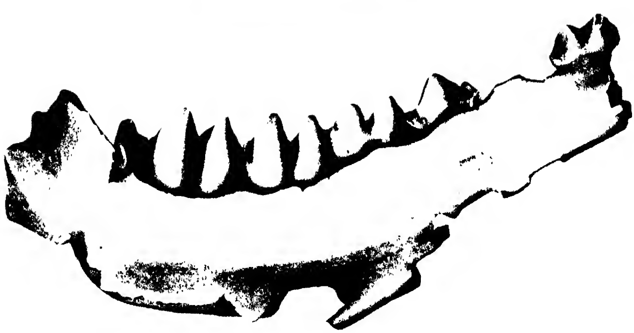


Fig. 2

Fig. 2 a

G. S. I. Calcutta

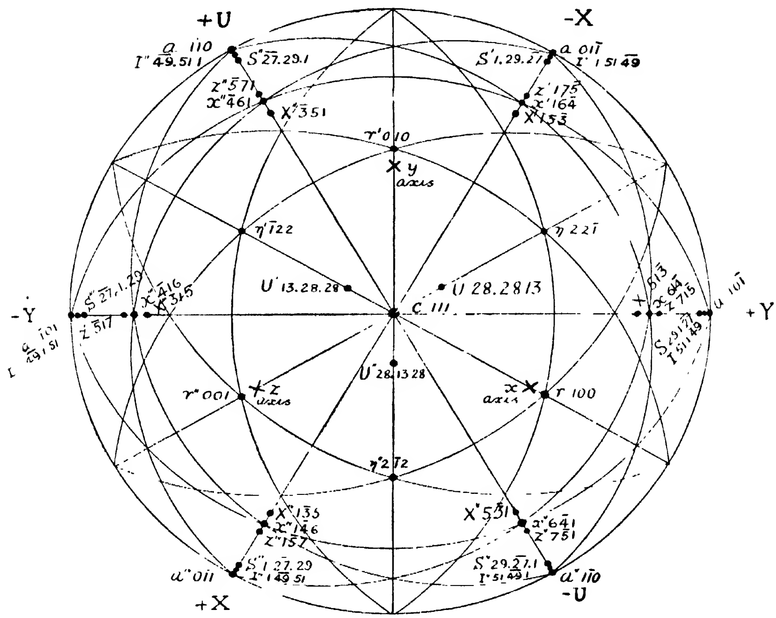
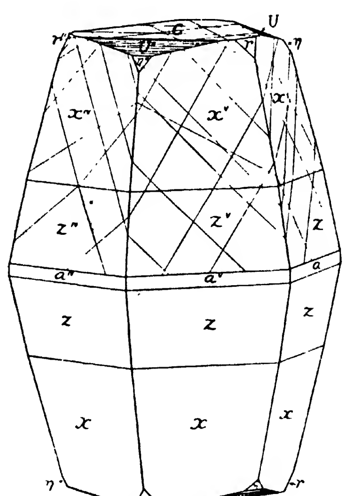
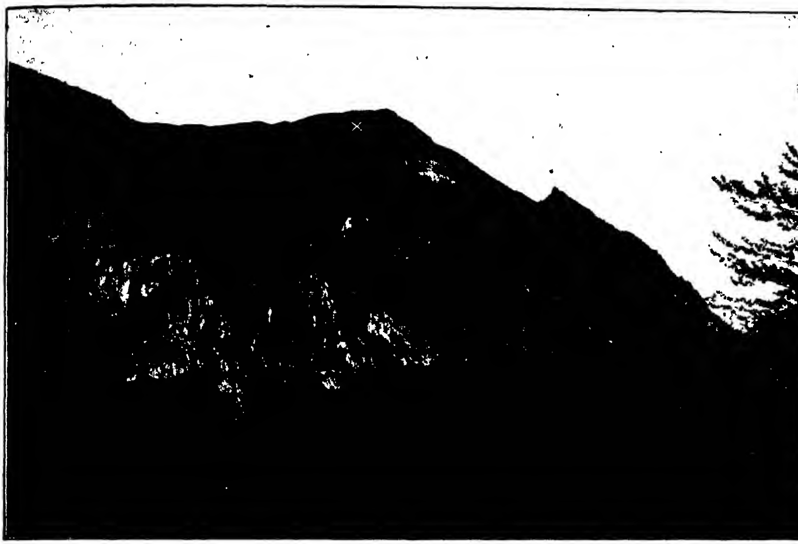


Fig. 1.



L. L. Fermor. Fig. 2. G. S. I. Calcutta.

HEMATITE FROM KAJLIDONGRI, JHABUA STATE, CENTRAL INDIA.



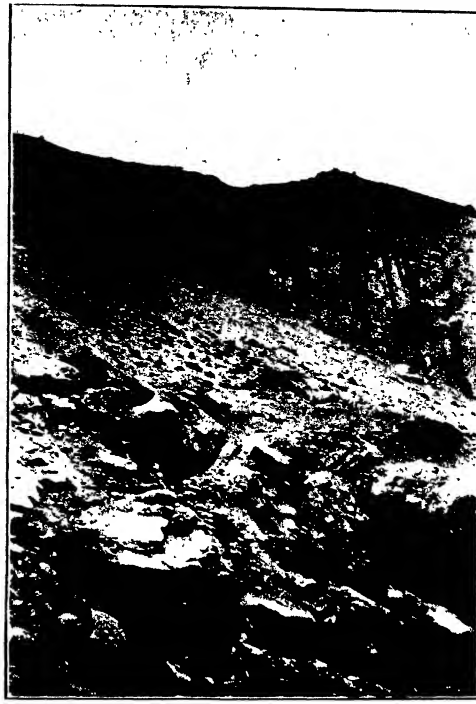
DEVONIAN IN HILLS OPPOSITE RESHUN, CHITRAL.

× Fossiliferous beds

Photo. by H. H. Hayden. *G. S. I. Calcutta.*

DEVONIAN ON KORAGH SPUR, CHITRAL.

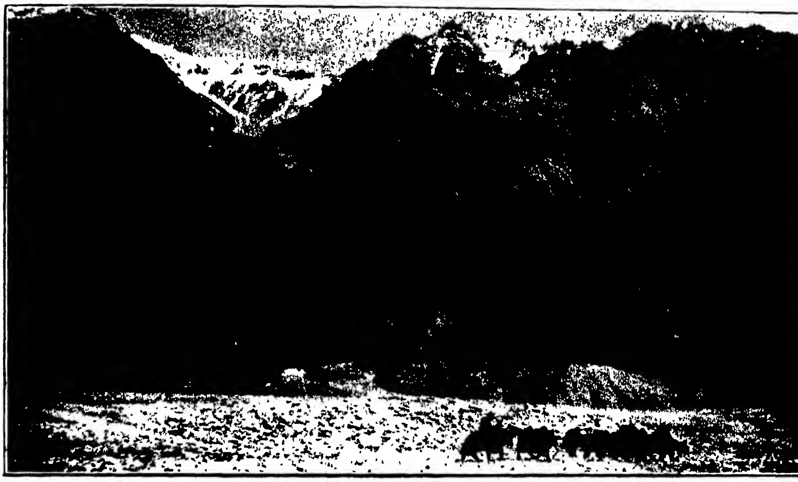
(a) Limestone with *Spirifer Verneuili* and corals.
(b) Shaly limestone with *Atrypa aspera*.
(c) Quartzite and limestone with many corals.



FOLDED CONGLOMERATE IN VALLEY BEHIND RESHUN.

Photo. by H. H. Hayden. *G. S. I. Calcutta.*

DASHT-I-BAROGHIL AND SAKEZ JARAB RANGE (GRANITE) FROM THE BAROGHIL PASS.



SLATES AND ANDESITES IN HILLS ON LEFT BANK OF KARACHUKAR RIVER BETWEEN MINTAKA AND BEYIK

Photo. by H. H. Hayden. *G. S. I. Calcutta.*

THE RUSSIAN PAMIRS, AS SEEN FROM THE TOP OF THE LAKHSHAKH PASS; LOOKING WEST.

JURASSIC AT HEAD OF KEKCHAKI VALLEY.
× Perisphinctes beds.

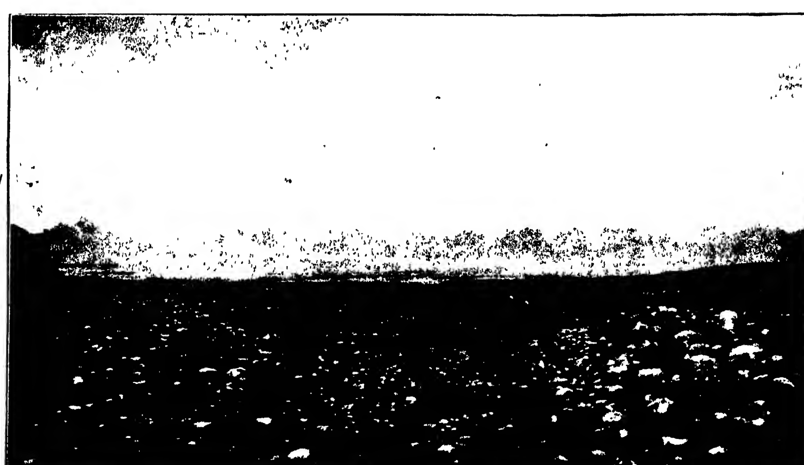
W  E

Photo by H. H. Hayden. *G. S. I. Calcutta.*

THE KASHGAR RANGE FROM NEAR MUJI.

Fig. 1. × 9

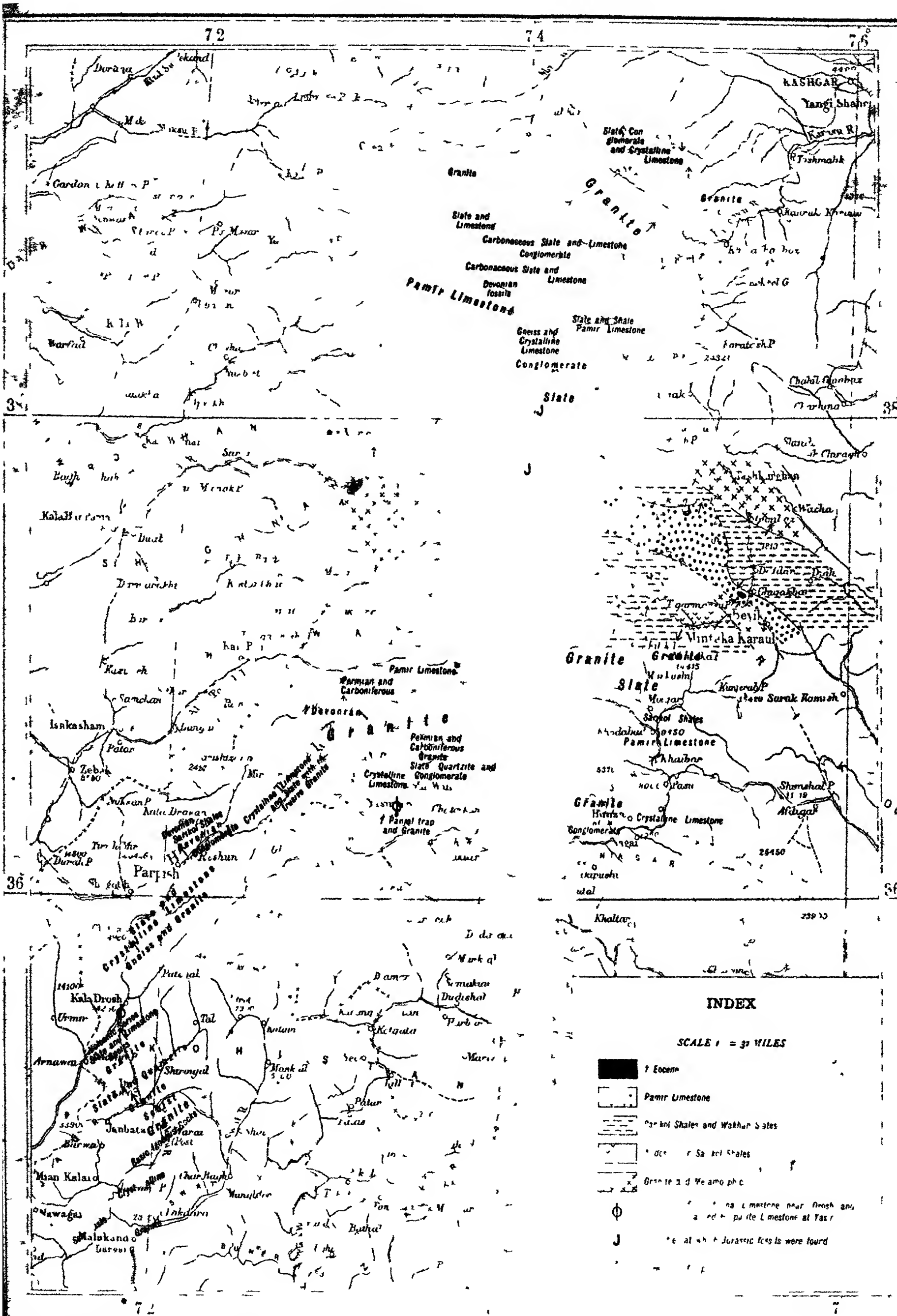
Fig. 2. × 15

Fig. 3. × 25

Fig 4. × 8

Photo. by H. H. Hayden.

G. S. I. Calcutta.


72
74
76
KASHGAR
Yangi Shahr
Slate, Conglomerate and Crystalline Limestone
Granite
Slate and Limestone
Carbonaceous Slate and Limestone Conglomerate
Carbonaceous Slate and Limestone
Devonian fossils
Pamir Limestone
Slate and Shale Pamir Limestone
Gneiss and Crystalline Limestone
Conglomerate
Slate
J
Isakasham
Zebak
Pamir Limestone
Permian and Carboniferous
Granite
Permian and Carboniferous Granite
Slate Quartzite and Conglomerate
Crystalline Limestone
Panjal trap and Granite
Devonian Sarikol Shales
Crystalline Limestone and Slate with Intrusive Granite
Sarikol Shales
Pamir Limestone
Crystalline Limestone
Conglomerate
Mintaka Karaul
Granite
Slate
Crystalline Limestone and Gneiss and Granite
Kala Drosh
Granite
Slate and Quartzite
Mian Kalai
Nawagai
Malakand
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SCALE 1 = 32 MILES
? Eocene
Pamir Limestone
Jurassic fossils were found

CALCUTTA
SUPERINTENDENT GOVERNMENT PRINTING, INDIA
8, HASTINGS STREET